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COMPARATIVE ANATOMY OF THE NORMAL AND DISEASED ORGANS OF ABIES BALSAMEA AFFECTED WITH ÆCIDIUM ELATINUM.

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(WITH PLATES XIV AND XV)

I. INTRODUCTORY.

WITHIN the last few years some attention has been given to the study of the deformations and anatomical changes that take place in plants when attacked by parasitic fungi. Such changes become more marked when the relations between host and parasite are such that there exists a sort of mutualism between the two. In many cases the hypertrophied organs of the host plant lose their photosynthetic power, and thus, by assuming parasitism, become more dependent on the normal parts of the host for their existence. This is always true of the so-called "witch brooms" (Hexenbesen) on species of Abies affected with *Æcidium elatinum*. Here the affected and hypertrophied part of the plant becomes a morphological unit, the anatomy and physiology of which departs from that of its normal homologues.

The anatomy of different species of Abies varies slightly under normal conditions. This is especially true of the leaves and younger branches, which in some species have tissues and

structures that may be rudimentary or wanting in others. Such structural and anatomical diversity either becomes more marked, or is entirely lost in hypertrophied or atrophied organs.

The deformations and anatomical changes resulting in the hypertrophied branches of *A. pectinata*, affected with *Æ. elatinum*, were first described in a general way by De Bary[1] who demonstrated that the "witch broom" was caused by a fungus.

Later, Hartmann[2] made a comparative anatomical study of the diseased and the healthy leaves and branches of the same witch broom. The writer[3] has made a comparative study of the diseased and the healthy buds of *A. pectinata*, as well as the formation and distribution of the abnormal resin canals that are formed in the wood of the branches affected with the same fungus. By comparing the witch broom of *A. firma* Siebold of Japan with that of *A. pectinata*, it was found that differences occur in the two, depending largely upon the differences existing in the normal leaves and branches of the two mountain species of Abies.

According to the analyses of Mayr,[4] the wood of *A. pectinata* contains the least per cent. of resin of any of the cultivated firs. *A. balsamea* differs from *A. pectinata* and *A. firma*, not only in its specific characters and peculiarities, as a large resin or balsam producer, but also in being a swamp species. For this reason, as well as its being exclusively an American species, one would expect to find marked structural and anatomical changes in the affected leaves and branches. The anatomy of the *Æ. elatinum* witch broom of *A. balsamea* has not been studied.

For the purpose of making a comparative anatomical study of this witch broom, material was collected from trees growing in a bog near Walker, on Leech lake, northern Minnesota, September 1896.

[1] DE BARY: Ueber den Krebs und die Hexenbesen der Weisstanne. Bot. Zeit. 1867.

[2] HARTMANN, F: Anatomische Vergleich der Hexenbesen der Weisstanne mit den normalen Sprossen derselben. Inaug. Diss. Univ. Freib. 1892.

[3] Ueber abnorme Bildung von Harzbehältern und andere zugleich auftretende anatomische Veränderungen in Holze erkrankter Coniferen. Inaug. Diss. Univ. München, 1896.

[4] MAYR, HEINRICH: Durability of resinous woods. Pop. Sci. Monthly **28**: 680.

II. GENERAL CHARACTERS OF THE WITCH BROOM.

Æ. elatinum Alb. & Schw. usually attacks the younger lateral branches of *A. balsamea* (L.) Mill. which take the infection either in the young shoots, or in the wounded bark of older ones. Branches over five years old seldom take the infection, differing in this respect from *A. pectinata*, which often has large swellings on the older branches and on the main trunk, due to this disease. It often happens that the terminal shoot becomes diseased, in which case the whole tree soon dies from insufficient light, not being able to increase in height fast enough to keep out of the shade of surrounding trees.

The irritation due to the fungus mycelium causes an increased growth of the bark and wood at the first point of infection, producing a so-called "boil" or tumor on the diseased branch. This tumor is always present and increases in diameter with the increase in age of the witch broom. The diseased annual shoot is shorter, but has a greater diameter than the normal.

Owing to the development of a greater number of the latent and lateral buds of the affected branches, the number of the diseased branches above the normal is greatly increased. In this way a sort of broom is formed. The leaves of the diseased branches spread on all sides like the leaves of the erect terminal shoots. This is partly due to the fact that the terminal as well as the diseased branches are all negatively geotropic, unlike the normal lateral branches which are diageotropic. On account of the absence of chlorophyll the diseased leaves have a yellowish color. The leaves of the diseased branches are about one half as long as the normal leaves of the lateral branches, but they are usually of the same length as the leaves of the normal terminal shoots. The normal leaves of the lateral branches are arranged nearly in one horizontal plane, not because the phyllotaxis is altered, but because the leaves are twisted more or less at the base, just above the pulvinus. It is easy, therefore, to distinguish between the normal and diseased branches, the normal ones always having this apparent distichous leaf arrange-

ment, while in reality they are still polystichous, like the leaves on the terminal shoot.

The *Æ. elatinum* witch broom on *A. balsamea* differs from that found on *A. pectinata* and *A. firma*, in that it seldom has normal branches growing together with the diseased ones above the tumor. The diseased branches are also more numerous, but correspondingly smaller. With the increase in height of the tree, the lower normal branches and the affected branches soon die on account of an insufficient amount of light. The witch broom dies with them, since it is dependent on the normal host for its food supply.

Although that part of the witch broom branch below the tumor is not diseased, its annual growth in diameter is less than in normal branches of the same age. The supply of food is transported to the witch broom, which grows at the expense of the normal parts of the host. This increased growth of the witch broom makes it much heavier than the normal branches, so that it is usually found suspended from larger limbs of the tree, or hanging near the tree trunk when the whole branch is affected. The living and actively growing ones on older trees, excepting where the trees are isolated, are always found near the top, where there is a sufficient food supply. Although photosynthesis is almost entirely absent in the witch broom, it is extremely sensitive, and dies from an insufficient amount of light.

As to the size of the witch broom on *A. balsamea*, the average diameter is from 15 to 30^{cm}, and the length from 20 to 60^{cm}.[5]

III. ANATOMY OF THE NORMAL AND DISEASED LEAVES.

1. *Normal leaves.*—The leaves of Abies are sessile, and without the prominent pulvini peculiar to the spruces. The leaves of the lateral branches of *A. balsamea* are more or less flattened, notched, or obtuse at the tip, grooved on the upper surface and

[5] *Picea nigra*, which grows with *A. balsamea* in the bogs of northern Minnesota, often has a witch broom 40 to 90^{cm} in diameter. The broom is caused by an increase in the number of branches, the internodes of which remain shorter than in the normal. This witch broom is not caused by *Æ. elatinum*, but by some other fungus or insect (Compare v. Tubeuf, Forst-naturw. Zeitsch. —: 76. *pl.* 5. 1893.

with a somewhat prominent midrib or keel below. They are always twisted at the base, giving them the distichous direction peculiar to species of Abies. The leaves on the erect shoots are not transversely heliotropic, or twisted at the base, but grow in all directions from the shoot. They are shorter and thicker than those of the lateral branches, more or less awl shaped, and are sharply pointed at the tip.

The number and arrangement of the stomata seem to vary in different localities. Masters[6] finds that the stomata are chiefly on the upper surface of the leaf. McNab[7] in his description gives two or more rows of stomata in the middle line near the apex on the upper surface, with two or more rows on each side of the midrib on the lower surface. Bastin and Trimble[8] find the greater number on the lower surface. I find that by far the greater proportion of the stomata are on the lower surface of the leaves of the lateral branches, which have one band of from 3 to 10 rows on the upper surface, and two bands of 8 to 10 rows on each side of the midrib on the lower leaf surface. On both surfaces the stomata are found in greater numbers toward the apex of the leaf. The more or less terete leaves of the terminal shoots have their stomata distributed about equally on all sides.

Cross sections of the leaves show a well marked cuticle covering the lignified epidermal cells, the outer walls of which are cuticularized and much thickened. Immediately under the epidermis lies the hypoderm when present (*fig. 1*). As to the presence or absence of a hypoderm, McNab[9] says that it is wanting. Engelmann[10] found that the leaves have scarcely any hypoderm cells above, and very few on the edges and keel, fewer than any other species of Abies. Sometimes no hypodermal cells

[6] MASTERS, M. T.: Anatomy and life-history of the Coniferæ. Jour. Linn. Soc. **27**: 250.

[7] MCNAB: New way of determining species of Abies. Robinson, The Garden **11**: 280.

[8] BASTIN and TRIMBLE: A contribution to the knowledge of some North American Coniferæ. Am. Jour. Pharm. **68**: 556.

[9] *Ibid.*, p. 280.

[10] ENGELMANN, G.: The American firs. Gard. Chron. N. S. **9**: 300. 1878.

were found. Bastin and Trimble[11] observed no hypoderm except along the midrib on the lower leaf surface. The presence or absence of strengthening, or hypodermal cells, however, depends entirely on the part of the leaf from which the cross sections are made. Hypoderm cells rarely occur in cross sections made above the middle of the leaf, while below the middle they are always present. Thus, numerous cross sections at five different parts of the leaves show in the following table their distribution (see page 315).

Longitudinal sections of the leaves show that the thick-walled hypodermal cells are long and bast-fiber like, with tapering, oblique, or blunt ends. The isolated cells are tapering at their upper ends and extend farthest up into the leaf. Their function, as is well known, is for strengthening the leaves. The leaves on the terminal shoots are much more rigid than the leaves on the lateral branches. This is due to the greater development of their hypoderm. Like the epidermal cells they are lignified. The walls are unequally thickened and often provided with pore canals. In *A. balsamea* one never finds them extending into the mesophyll, as they do in the leaves of *A. firma*. The number of hypodermal cells decreases from the base toward the tip of the leaf; but with the decrease in the number of hypodermal cells there occurs a corresponding increase in the number of stomata.

The mesophyll, which forms the chief substance of the leaf within the hypoderm, agrees in its main characteristics with that found in the leaves of most species of Abies. The two distinct layers of palisade cells extend around the rounded angles of the leaves. In the center of the mesophyll, and midway between the endoderm and outer angles of the leaf, lie the two circular resin canals, which are large in *Abies balsamea*. The resin canals are lined with the thin walled epithelial cells, which are themselves surrounded by one layer of thick-walled strengthening cells. These strengthening cells differ from the sub-epidermal ones in that they are shorter and not fiber-like.

[11] *Ibid.*, p. 556.

TABLE I.

CROSS SECTIONS OF LEAVES OF A. BALSAMEA, SHOWING THE DISTRIBUTION OF THE HYPODERMAL STRENGTHENING CELLS.

	Cross sections	Leaves of lateral branches	Leaves of terminal shoots
One millimeter above the base.	1. Upper surface. (Ventral.)	Hypodermal layer continuous, except where it is perforated by the stomata.	Hypodermal layer unbroken; often with double rows of cells.
	2. Lower surface. (Dorsal.)	Like 1. Layers often double at the midrib.	Like 1. Often with 2 to 4 rows of cells at the midrib.
	3. At the angles.	Single hypodermal layer unbroken.	Hypodermal layer consisting of 2 to 3 rows of cells.
Half way between middle and base.	1. Upper surface.	Hypodermal cells present, but more or less isolated.	Hypoderm unbroken, often double rowed.
	2. Lower surface.	Like 1, but more numerous, forming a continuous layer at midrib.	Like 1, often with three rows at midrib.
	3. At the angles.	Like 1.	Layer continuous, often double rowed.
At the middle.	1. Upper surface.	Hypodermal cells seldom present.	Hypodermal layer often broken by mesophyll and stomata cells.
	2. Lower surface.	Like 1. Single layer often continuous at the midrib.	Like 1, but never broken at the midrib where it is often double.
	3. At the angles.	Like 1.	Hypoderm unbroken.
Half way between middle and apex.	1. Upper surface.	Hypoderm wanting.	Hypodermal cells isolated when present.
	2. Lower surface.	Usually 2 to 5 strengthening cells at the midrib.	Hypoderm continuous at midrib. At other parts, cells isolated.
	3. At the angles.	Hypoderm wanting.	6 to 10 cells present in one continuous layer.
One millimeter below apex.	1. Upper surface.	Hypoderm wanting.	Hypodermal cells scattered and isolated when present.
	2. Lower surface.	Hypoderm wanting.	Like 1, but with a continuous layer of 8 to 15 cells at the midrib.
	3. At the angles.	Hypoderm wanting.	2 to 5 hypodermal cells usually present.

The elliptical endoderm or bundle sheath, which lines the mesophyll on its inner side, separating it from the central pericycle and fibrovascular bundle, consists of one very distinct layer of large, usually oval, non-lignified parenchyma cells.

The pericycle consists of more or less thickened, lignified parenchyma cells, destitute of chlorophyll. The greater part of it lies on the dorsal side of the leaf, while the vascular bundle occupies the ventral. The pericycle consists of two kinds of cells, forming two distinct areas. First, a central, well marked area with non-pitted cells, varying greatly in size and in the thickness of their cell walls (*fig. 2*). These cells separate with 2 or 3 layers the two divisions of the vascular bundle in the middle part of the leaf, where the bundle is bifurcated. They extend up into the ventral or xylem side of the bundle, forming a wedge shaped area of thick walled cells. On the phloem side they are thinner walled, but larger, and fill up the whole center of the pericycle, extending dorsally to the endodermis in the leaves of the lateral branches. But in the leaves of the terminal shoots, the non-pitted area is separated from the endodermis by a layer of the pitted parenchyma. Second, the pitted parenchyma of the pericycle, which forms the so-called transfusion tissue of von Mohl. This part consists of linear lignified cells with bordered pits on their ends, as well as on their lateral walls (*fig. 3*). The transfusion tissue is not as well developed in the leaves of the lateral branches as in the leaves of the terminal shoots. In the former there are two small areas, each one lying dorsal to the outer half of the two phloem areas. Each area of the transfusion tissue extends along the endoderm about one-eighth of its circumference. In the leaves of the terminal shoots the two parts of the transfusion tissue begin at the outer edges of each of the phloem parts and follow the endodermis until they meet, thus making a semicircular area of transfusion tissue, 2 to 6 cells deep on the dorsal side of the leaf beneath the endodermis. More than one-half of the pericycle of the leaves of the terminal shoots consists of transfusion tissues.

The vascular bundle lies near to the endoderm on the ventral

side of the leaf. At the base and apex of the leaf the bundle is undivided; but in the middle, and for the greater part of its length, it is bifurcated. The phloem part (dorsal) consists of smaller and less thickened cells than those of the xylem (ventral). The phloem and xylem cells are arranged in more or less distinct rows, usually separated by medullary rays. The cells of the medullary rays frequently contain crystals of calcium oxalate.

2. *Diseased leaves.*—The diseased leaves are about one-half to three-fourths as long as the normal ones on the lateral branches, but they have about the same length and thickness as the leaves of the terminal shoots. The diseased leaves growing, as they do, on negatively geotropic branches, are more or less homologous to the normal leaves of the terminal shoots. In comparing the anatomy of the diseased and the healthy leaves, those of the lateral shoots should be considered. In Hartmann's comparative anatomical study of the witch broom of *A. pectinata* the leaves of the lateral branches only are considered. The cuticle of the diseased leaves is less thickened than that of the normal leaves. The number of stomata and stomatal rows varies according to the size of the leaf, as well as to the severity of the mycelial infection. There are only about one-half as many stomata in the diseased as in the normal leaves.

The epidermal cells vary greatly in size; they have larger lumina than the normal and are less thickened, especially on their inner sides, which are seldom laminated, or provided with pore canals. The hypodermal cells are present, especially in the basal half of the leaf. They are more irregularly distributed, often forming nests and groups. The cells are often twice as large and thick walled as the normal hypodermal cells (*fig. 4*). As in the normal leaves, the number of hypodermal cells decreases from the base toward the apex, but with the decrease in the number of hypodermal cells an increase takes place in the number of stomata on the upper and lower leaf surfaces. On account of the unequal thickening and irregular distribution of their epidermal and hypodermal cells, the diseased leaves shrivel

up on drying, soon after the ripening of the æcidia. The epidermal and hypodermal cells are lignified.

The mesophyll is made up of a mass of large, irregular cells, with large intercellular spaces. There is no differentiation into palisade tissue and spongy parenchyma. The fungus mycelium is found in all the cells and intercellular spaces. The two resin canals are also present in the diseased leaf. Their epithelial cells are usually larger and more irregular than the normal. The strengthening cells are not thickened, hence the resin canals become irregular in form and size, and often lose their identity in older leaves.

The endoderm is seldom distinguishable as such, its cells forming no ring.

The two lignified parenchyma areas of the pericycle are well defined, especially at the basal portion of the leaf. The transfusion tissue is nearly always present, often in one to three small areas on the dorsal side of the phloem part of the vascular bundle. In well developed leaves, especially in sections made near the base, the transfusion tissue fills up more than one-half of the pericycle. It is unlike the pitted parenchyma of the normal pericycle, in that its cell walls have simple as well as bordered pits. The cells are also irregular in form, and often thicker walled. The bordered pits are often twice the size of the normal (*fig. 5*).

The non-pitted parenchyma of the pericycle differs from that in the normal, in that its cells are always thicker walled and usually larger, but fewer in number. The two or three layers of cells, separating the bifurcated bundle, as well as the cells of the wedge shaped portion on the ventral side of the bundle, consist mainly of thick walled fibrous cells, which are seldom found thickened in the normal leaves (*fig. 6*).

The vascular bundle is double excepting at the base and apex of the diseased leaf. The phloem cells are larger, and the xylem cells thicker walled, than in the normal. They are not arranged as regularly in rows, and the rows, when distinguishable, are not separated by medullary rays, these being absent in the diseased leaves.

In the following table the most important differences in the structural units of the normal and diseased leaves are given:

TABLE II.

TABLE SHOWING THE COMPARATIVE ANATOMY OF THE NORMAL AND DISEASED LEAVES OF A. BALSAMEA.

Leaf structures	Normal leaves	Diseased leaves
Cuticle.	Well developed. Smooth on outer surface, irregularly thickened on the inner, fitting closely between the somewhat irregularly thickened and projecting epidermal cells.	Cuticle present, but less developed.
Epidermis.	Cells thicker walled on outer than inner sides. Often laminated and provided with pore canals.	Epidermal cells more irregular than in normal; less thickened and seldom laminated, and provided with pore canals.
Stomata.	More on lower than on upper leaf surface. The number increases from base toward apex as the number of hypodermal cells decreases.	Like the normal, but fewer on both surfaces. Bands of stomata have fewer rows.
Hypoderm.	Well developed at basal half of leaf. Number of cells decreases from base toward apex as the number of stomata increases.	Hypodermal cells fewer, but usually larger, thicker walled and more irregular than in normal leaves. Cells often aggregated.
Mesophyll.	One to three layers of palisade cells on ventral side, rich in chlorophyll. Remaining part consists of spongy parenchyma.	No distinction between palisade cells and spongy parenchyma. Chlorophyll rarely present.
Resin canals.	Circular or nearly so. Consisting of two layers of cells — epithelial and strengthening. The latter are thick walled.	Irregular; varying in form and size, on account of the absence of the layer of strengthening cells.
Endodermis.	One layer of oblong or elliptical, thin walled cells, forming a regular ellipse bounding the mesophyll and pericycle.	Endodermis seldom distinguishable. Cells irregular in form and size. No distinct boundary between mesophyll and pericycle.

TABLE II.—*Continued.*

Leaf structures	Normal leaves	Diseased leaves
Transfusion tissue of the pericycle.	Always present. Cells have bordered pits only. Cells lignified.	Nearly always present. The lignified parenchyma cells unequally thickened. Cells have simple as well as bordered pits. Bordered pits larger than normal.
Non-pitted parenchyma of the pericycle.	Lignified parenchyma cells varying in size and thickness of their walls. Found on both sides, but mostly on the dorsal side of the bifurcated bundle.	Lignified; more irregular in form and size. Larger and thicker walled than in normal. Cells often fiber like.
Fibrovascular bundle.	Phloem and xylem consisting of from 5 to 10 rows of cells. Rows usually separated by medullary rays, the cells of which contain crystals of calcium oxalate.	Phloem and xylem less developed than in normal. The cells are often larger and thicker walled. Medullary rays and crystals of calcium oxalate are absent.

IV. ANATOMY OF THE NORMAL AND DISEASED BUDS.

1. *Normal buds.*—The buds of *A. balsamea* are conical or globular. In winter condition they are covered by a layer of resin 1 to 2^{mm} thick at the apex of the bud. The bud scales are destitute of any epidermal hairs, but the edges of the outer exposed scales, as well as the inner ones, are fringed with marginal hairs. The number of bud scales does not vary much in different buds, the smaller and lateral ones usually having the same number as the larger and terminal ones. The scales of the terminal buds are relatively larger.

The epidermal cells of the outer surface (morphologically the under surface) of the exposed scales are usually oblong, and 2 to 8 times as long as broad, usually with oblique ends. When viewed from the exterior, and in cross sections, they are found to be about twice as deep as broad, which is due mainly to the thickened outer wall of the exposed epidermal cells. This thickening of the outer wall is greater in the center of the exposed cell wall; hence, the outer wall of each epidermal cell

appears in cross sections as a protuberance from the cell. The thickened walls shows a laminated structure. The side walls are not thickened except at places where the thickening has proceeded from without inward, often unequally, so that pore canals are formed. These are best seen when the scales are mounted in chloral hydrate and viewed from the exterior. The inner wall usually remains unthickened. Variations, however, occur in the different parts of the bud scale in this and other species of Abies. Thus Schumann[12] found that in the upper part of the bud scales of *A. pectinata* the epidermal cells are thickened on all their sides. This I find takes place in *A. balsamea* also. The second, or hypodermal layer of cells, remains thin walled. The epidermis on the inner side (morphologically the upper) of the exposed scales, together with the second or hypodermal layer of cells, is usually thickened equally on all sides. The epidermal cells of the inner scales covering the growing point are thin walled like the cells of the mesophyll.

I have not succeeded in finding any stomata on the bud scales of *A. balsamea*. It is quite possible, however, that they occur, but if present, they are less frequent than in bud scales of *A. pectinata*, where I have found them, contrary to the statements made by Grüss[13] and Schumann,[14] who both say that they are never found on the bud scales of *A. pectinata*, even in a rudimentary condition.

The mesophyll or parenchymatic portion, homologous to the mesophyll of the normal leaf, is composed of from three to six layers of parenchyma cells, many of which contain chlorophyll.

The margins of the outer, as well as of the inner scales, are fringed with filamentous or hypha-like hairs (*fig.* 7). Although the marginal hairs of the outer scales are exposed to the atmosphere, they still remain thin walled, differing in this respect from the exposed epidermal cells and hairs, which always become

[12] SCHUMANN, C. G.: Anatomische Studien über die Knospenschuppen von Coniferen und dicotylen Holzgewächsen. Bibliotheca Botanica 15:3. 1889.

[13] GRÜSS, J.: Beiträge zur Biologie der Knospe. Jahrbücher f. wiss. Bot. 23:642.

[14] *Ibid.*, p. 2.

thickened and cuticularized. Tubeuf[15] finds the marginal hairs only on the inner scales of the buds of *A. pectinata*. They are present, however, and always found on the outer scales, also, not only in *A. pectinata* but in all species of Abies whose buds are in their winter condition covered with a layer of resin. The marginal hairs of the outer scales are always filled with resin.[16] With the drying of the cells of the marginal hairs, which always remain thin walled and connected with the mesophyll, through which the resin canals run, the resin passes from the resin canals and inner cells to the exterior, until the bud is covered with a layer of resin sufficiently thick to prevent any further transpiration of moisture and exudation of resin.

The endodermis cannot be distinguished. The central bundle with its pericycle is composed only of a number of smaller aggregated cells in the center of the scale. No differentiation into xylem and phloem is present.

A striking character in the structure of the bud scales of *A. balsamea* is that from two to six resin canals are often present in each scale. The greater proportion of the scales have two canals, the normal number of their morphological equivalents, the leaves, but in cross sections of many scales, especially the inner ones, one often finds in every bud some scales which have from two to six resin canals (*figs. 8* and *9*). As to the origin of the increased number of resin canals, whether they are due

[15] TUBEUF: Haarbildungen der Coniferen. Forst.-naturw. Zeitsch. 1896. Sonderabdruck S. 19 u. 21.

[16] Since the resin canals do not open to the exterior of the bud scales or any other part of the plant, there can be no doubt but that there exists a definite relation between the marginal hairs of the bud scales and the exudation of resin on the buds. It is evident that the resin, which begins to exude in the late summer and fall, as soon as the scales begin to dry up, must diffuse through cell membranes. That resin diffuses through cell walls has been demonstrated (compare Grüss, *ibid.*, p. 642; Mayr, *Pop. Sci. Monthly* **28**: 680; and Harz der Nadelhölzer 80. 1894). It does not, however, diffuse through the cuticularized and thick walled epidermis cells of the outer scales.

In many conifers, *e. g.*, *Picea nigra* and *P. excelsa*, whose buds are not resin-covered, the bud scales are coriaceous and destitute of resin canals. The marginal hairs of the outer scales of *P. nigra* are thick walled and the inner scales seldom have any marginal outgrowths.

to the branching of the two canals already present, or whether they are peculiar to the scales of *A. balsamea*, I am not able to state. It appears, however, that in all species of Abies whose buds are covered over with resin in the winter, there is an increase in the amount of resin production in the bud scales over that produced in the normal leaves, and hence it is probable that more than the normal number of canals can develop in the bud scales. The resin canals are seldom surrounded by a layer of strengthening cells.

The growing point with its rudimentary leaves is covered over by the inner scales, which are imbricated, and cover the apex of the growing point four to six layers deep. Longitudinal sections of the growing point show that in its winter condition no tissue differentiation whatever has taken place. The central portion (plerome) has pith characters. In cross sections no resin canals or rudimentary bundles are present.

The septum (Knospenscheide or Scheidewand), which makes the break in the pith at the annual nodes in most species of conifers, is well developed in buds of *A. balsamea*. It consists of from six to ten layers of thick walled cells, forming a diaphragm, separating the pith of the growing point and young shoot from the pith of the last year's internode. Immediately below the diaphragm there is always to be found a mass of loosely connected, rounded pith cells (*fig. 10, f, g*), which in older internodes have separated from the septum, or diaphragm, so that a cavity is formed. This empty chamber is seldom present below the septum of the bud in its winter condition. In the spring, however, as soon as the differentiation of the peripheral cells of the plerome begins, and the xylem cells of the vascular bundle begin to elongate, the septum is partly raised above the loose tissue of the pith of the last year's internode, thus forming the pith chamber, which is always present below the septa of the first and second year old and older internodes.

Fritsch[17] found that the cells of the septum are in the form

[17] FRITSCH, CARL: Die Marklücken der Coniferen. Schriften d. Kgl. physik. Ökonom. Gesellschaft zu Königsberg **25**: 50. 1885. [Separat-Abdruck p. 6.]

of irregular three to four sided prisms, whose sides are more or less arched. In cross sections the cells appear to be pressed together in the direction of the long axis of the stem, their lumina being longest in the radial direction. The cells are about equally thickened except where the pits appear to meet, being separated only by the primary cell wall.

As has already been stated, the leaves of Picea have prominent pulvini at their bases. Masters[18] calls attention to the fact that the central fibrovascular bundle of the leaf passes directly from the axis into the leaf, and does not traverse the prominent swelling at the apparent decurrent base of the leaf. The pulvini, therefore, do not form a part of the leaf, being mere outgrowths from the sub-epidermal and corky layers. In buds of Picea, especially in the terminal buds,[19] these swellings or pulvini are collected into a mass surrounding the bud. On this account the bud appears swollen beneath the bud scales, which, like the leaves, have these swellings and thus aid in making the basal portion of the bud assume this fleshy character.

The same is true in species of Abies, except that the apparent decurrent basal swellings of the leaves are much less marked.

The terminal shoots and buds of *A. balsamea* show to a great extent the same characters as those of Picea, the buds having he characteristic swelling below the bud scales. The bud scales are also provided with thickened bases, which in their compact arrangement in the bud have lost their decurrent aspect. The basal swellings of the innermost (uppermost) bud scales, covering the sides and apex of the growing points, differ essentially in structure from the lower and outer scales in that they consist of a mass of thick walled cells, very similar in structure to the cells of the pith septum, above which they project (*fig. 10, c*). In cross sections made at the base of the septum, a ring of this collenchymatic tissue can be seen in the section (*fig. 10, b*). Busse[20]

[18] MASTERS, M. T.: Note on the relation between morphology and physiology in the leaves of certain conifers. Jour. Linn. Soc. Bot. **27**: 547. 1879.

[19] Compare Tubeuf, *ibid.*, p. 19.

[20] BUSSE, W.: Beiträge zur Kenntniss der Morphologie und Jahresperiode der Weisstanne. Flora **77**: 121.

calls the ring of this tissue in *A. pectinata* the wall of the cup, the pith septum being its bottom. The wall of this cup surrounds the growing point in winter; the youngest inner bud scales grow from this annulus. That this annulus of thick walled tissue at the base of the innermost scales does not form a part of the internodal pith septal layer is shown by the fact that the xylem and phloem cells of the last year's internode extend up, and separate the septum from the basal swellings of the inner scales (*fig.* 10, *a*). In older internodes it is found dried up in the outer bark, together with the remains of the bud scales. The thick walled area of the basal swelling of the inner scales is composed of from 6 to 10 layers of cells of parenchymatic origin, shown by their pitted walls. That this annulus of strengthening cells, together with the pith septum, forms an additional protection to the bud in its winter condition, there can be no doubt.

TABLE III.

	Bud no.	Position	Diameter in mm.	No. of scales exposed	No. of inner scales	Total number of scales
Normal buds	1	Terminal on erect shoot	4	20	9	29
	2	" " " "	4½	20	10	30
	3	Axillary on erect shoot	2½	17	7	24
	4	" " " "	2½	19	8	27
	5	Terminal on lateral shoot	2½	16	8	24
	6	" " " "	3	19	7	26
	7	Axillary on lateral shoot	2	16	9	25
	8	" " " "	1½	18	6	24
Diseased buds	1	Terminal	2½	30	8	38
	2	"	2½	27	9	36
	3	"	3	29	7	36
	4	Axillary	1½	25	6	31
	5	"	1¾	27	7	34
	6	"	1½	24	6	30

2. *Diseased buds.*— The diseased buds are more numerous, shorter, and somewhat larger than the normal. They are covered with a layer of resin, and in this respect are well protected. Like the normal buds their scales have no epidermal hairs. The diseased buds are covered over with a greater number of bud scales

which are smaller than the normal. In the third table the number of exposed and of inner scales of normal and diseased buds are given.

From the above table one sees that the number of the inner scales does not vary much in the normal and the affected buds. The number of exposed scales, however, have been increased from 16 to 20 in the normal, to 24 to 30 in the diseased buds. More of the diseased scales are, therefore, provided with a cuticularized and sclerotic epidermis than the normal. The total number of scales has also been increased from 24 to 29 in the normal to 30 to 38 in the diseased.

One reason for this increase in the number of scales in the diseased buds is their relative smaller size. The buds thus require more scales to cover the growing point, which is also larger in diseased than in healthy buds.

The diseased scales, like the normal, have no stomata. The marginal hairs are present and as in the normal scales remain thin walled. Those of the outer scales are always filled with resin soon after the resin exudation begins.

The outer exposed epidermis is composed of shorter and more irregular cells than that of the normal. Cross sections of the scales show that the outer wall of the epidermal cells is thickened and cuticularized. The thickening never extends to the side or inner walls. The walls are not more than half as thick as in the normal epidermal cells. The inner, upper epidermis is rarely thickened excepting at the base of the inner scales.

The mesophyll, which is less developed than in the normal scales, consists of larger but fewer cells. The resin canals are fewer, more irregular in size and form; more than two are never present. They contain fewer epithelial cells, which vary greatly in size. Many of the diseased bud scales have no resin canals.

The endodermis, pericycle, and central vascular bundle, which in the normal scales have been reduced to a few cells, smaller than the surrounding mesophyll cells, are not found in the diseased scales.

The bases of the inner scales have the same fleshy tissue composed of thickened, strengthening, and protecting cells. This tissue, as in the normal buds, projects above the base of the young growing point. There is no difference whatever in the development of this tissue in the normal and the diseased scales.

The rudimentary leaves and apex of the growing point are larger, being composed of larger cells than the normal. This is especially true of the pith or central plerome cells. No resin canals are present in the growing point. The pith septum at the base of the growing point is composed of about the same number, and of equally thickened, but fewer pitted cells than the septum of the normal bud.

The distribution of the fungus mycelium in the diseased bud varies in the different structural units. It is always found in the mesophyll of the bud scales where the haustoria penetrate into almost every cell, except the resin canal and epithelial cells surrounding the canals. The same is true of the resin canals of the diseased leaves. The mycelium also is present in the loose pith tissue below the septum. All the remaining parts of the bud are destitute of the fungus mycelium. It is never found in the growing point and rudimentary leaves, nor in the internodal pith septum and similarly thickened cells, forming the ring of projecting tissue surrounding the growing point at the base of the inner bud scales. It is not surprising to find that the mycelium is absent in the thick walled cells of the septum, and in the annulus surrounding the lower half of the growing point, since the cells of this tissue have no cell contents whatever, nor does the mycelium penetrate the thickened cell walls. On the other hand it is surprising not to find the fungus mycelium in the growing point and rudimentary leaves, which are covered over with the inner scales. In almost every cell of these scales the actively growing fungus mycelium is present. This absence of the mycelium in the growing point is undoubtedly due to the presence of negatively chemotropic substances, or to periodic variations in the amount of starch, tannin, and

other plant products, occurring at different seasons of the year. Thus Busse[21] found that the maximum amount of starch in the growing point of *A. pectinata* occurs in May, and that from this month on there is a decrease until in the fall and winter, when the minimum is reached. He found also three different tannins in the growing point, varying in amount at different seasons of the year.

It often happens that buds are found which have been killed by the mycelial infection of the growing point. That this infection has taken place from the inner scales there can be no doubt, since the mycelium hibernates here, and infects the rudimentary leaves and young shoots as soon as they begin to develop in the spring. The mycelium is thus evenly distributed in the bark of all diseased shoots above the tumor of the affected branch. If it were not for this mycelial infection of the young shoots and rudimentary leaves by the bud scales and parenchymatic tissue of the primary cortex, healthy leaves would be found on affected branches. This never occurs. It often happens, however, especially on the witch broom of *A. pectinata* and *A. firma*, that the leaves and young shoots are not infected. They then develop like the normal. This shows that the mycelium does not spread to any great extent in the bark after the tissue differentiation has taken place. The mycelium never spreads more than 2 to 3^{mm} each year in the healthy bark below the swelling or tumor.

V. ANATOMY OF THE NORMAL AND DISEASED SHOOTS AND BRANCHES.

1. *Normal shoots and branches.*—The leader or terminal shoots depart in their general characters from the lateral, not only in the morphology and anatomy of their leaves, but also in the anatomy and morphology of their axes. The leader shoots are longer and have a greater diameter than the lateral. This greater diameter is due mainly to the greater development of the pith and primary cortex, the most important conducting tissues of the first year's internode. The vascular bundles of

[21] *Ibid.*, p. 170

the first year's terminal and lateral shoots are about equally developed. In the second year's growth, however, the vascular bundle, especially the wood of the terminal shoots, shows a decidedly increased growth over that of the lateral. Thus cross sections of the main and lateral axes taken from the same trees give the following radial widths of their principal parts:

TABLE IV.

Axes		Outer bark Epidermis and periderm	Middle bark Primary cortex	Inner bark Secondary cortex	Wood	Pith
One year old	Terminal	166μ 132 220	1348μ 1494 1245	83μ 96 90	249μ 192 288	1520μ 1610 1411
	Lateral	160 249 144	830 736 256	85 84 64	224 272 119	720 800 324
Two years old	Terminal	260 224 230	970 980 846	240 250 215	1040 1318 1246	1440 1250 1373
	Lateral	256 225 210	800 384 348	140 128 123	640 280 394	560 420 390

From the second year on this increased growth of the wood and secondary cortex of the main axes over that of the lateral branches continues.

Outer bark.—The terminal shoots have no epidermal hairs. The epidermis, however, of the one year old lateral shoots has numerous short, one to five-celled hairs,[22] the cells of which soon become thick walled. The cells are usually unequally thickened and pitted (*fig. 11*). The epidermal hairs of the lateral branches thus differ from the marginal hairs of the bud scales, which remain thin walled. Since the epidermal hairs

[22] Compare Tubeuf, *ibid.*, p. 35.

soon dry up and fall off, they are seldom found on two-year old or older internodes.

The cuticle is less developed than the cuticle of the leaves. The epidermal cells are thickened more on their outer than inner walls. The periderm or corky layer of the outer bark of the one year old shoots is composed of from 4 to 6 rows of cells, but through the activity of the cork cambium more layers are formed the second and following years. *A. balsamea* forms cork scales only after reaching a certain age. Thus one usually finds trees 20 to 50 years old with a smooth bark and without any distinct cork scales. The original epidermis is still present and can be peeled off in small scale-like layers.

Primary cortex (*middle bark*).—The outer part of the primary cortex, or middle bark, beneath the peridermal layers, is composed of from 4 to 6 strengthening collenchyma cells. The greater part of the chlorophyll parenchyma remains thin walled during the first year. Many of the cells, however, become thick walled and sclerenchymatous. This thickening of the parenchyma and differentiation into mechanical tissue continues during the second and following years. The sclerenchyma cells soon form short branches, the cell lumen of the original cell extending into them, giving them the appearance of branching bast fibers. Hartmann[23] calls these cells in *A. pectinata* bast fibers. That they are not bast fibers is shown by their parenchymatic origin and profuse branching. Their cell walls are laminated and pitted. They are usually aggregated together in nests of from 3 to 10 cells, forming areas of mechanical tissue.

Many of the parenchyma cells of the primary cortex function as secretion reservoirs for tannin and mucilage. Crystals of calcium oxalate are seldom found in the primary cortex. The tannin cells are scattered over the whole primary cortex, and do not vary in size and form from the chlorophyll parenchyma cells. The mucilage cells are spherical, ovoid, or elliptical, and vary in diameter from 30 to 240 μ. The largest ones are

[23] *Ibid.*, p. 27.

found in the primary cortex of the older branches. They increase in size by the distention of their cell walls; consequently the larger mucilage cells are thinner walled.

The resin canals are always lined with one layer of epithelial cells. Surrounding this layer there are always present one or two layers of collenchymatic strengthening cells. No resin canals are formed after the first year, and during the first year only in the meristem tissue of the developing shoot, where they reach their definite size as soon as the tissue differentiation has taken place. After the resin canal has reached its definite size, the epithelial lining probably loses its resin secreting function; but its cells still remain thin walled and are able to divide, like ordinary parenchyma cells.

It is evident that with the increase in the diameter of the main axis and the peripheral growth of the bark, disturbances must occur in the resin canals of the primary cortex. As has already been stated, the primary cortex of *A. balsamea* remains alive, and is not thrown off by the formation of cork scales before the tree stems are from 50 to 100 years old. With the increase of the peripheral growth of the tree trunk, however, the resin canals are often disturbed by the cork cambium, which at places penetrates deeper into the primary cortex. Mayr[24] has demonstrated that as soon as a resin canal comes in contact with the cork cambium, the canal is filled up by the ingrowing of its epithelial cells, forming the so-called tyloses. In the development of each internode, a new system of resin canals is formed in the primary cortex, so that the canals of one internode do not connect with the canals of the adjoining internodes. The canals are always filled with an oleo-resin, so long as the formation of cork has created no disturbance in the turgescence by the loss of water from the cells surrounding the resin canals. The main resin canals are vertical and traverse the whole length of the internode. In older stems they are not always vertical, since the peripheral growth of the bark and main axis is not always

[24] MAYR, H.: Harz der Nadelhölzer; seine Entstehung, Vertheilung, Bedeutung und Gewinnung 21. 1894.

symmetrical. A part of the primary cortex, and with it the resin canals, may be cut off by the cork cambium. This may be only local, or include only a part of the resin canal. The part of the canal thus disturbed is soon filled by the ingrowing epithelial cells. It is evident that, with the intrusion of the epithelial cells, the resin is pressed into the undisturbed part of the canal, causing this part to distend and increase in size, by the radial and tangential division of its epithelial lining (*fig. 10, b* and *c*). In this way resin vesicles are formed, often two or more in each canal. Other factors besides the disturbances due to the cork cambium may cause tylosis; thus great temperature variations of exposed and shaded sides of the stem, and with it variations in the transpiration of the bark. Tylosis begins in the resin canal as soon as the loss of water from the cells and cell walls reaches a certain per cent. With the filling up of the resin canal the radial and tangential division of the epithelial cells of the resin vesicle still continues, and with it the vesicle increases in size, receiving at the same time all or nearly all of the resin of the original canal. Not only do the resin vesicles contain all the resin of the canal, but also the resin which is all the time being secreted by the tissues of the primary and secondary cortex. The great quantity of resin secreted by *A. balsamea* tends also to form the vesicles, as they begin to form even in four-year old internodes, and before tylosis has begun. With the increase in age of the bark the vesicles increase in size, so that in trees 20 to 100 years old the trunk of the tree always contains the balsam vesicles in great numbers. The larger ones are always found on the lower part of the tree trunk. They can be seen on the outside, where they appear as swellings or blisters on the bark. The periderm and outer part of the primary cortex give way to the pressure of the vesicle as it increases in size by the radial and tangential division of its lining cells. With the increase in size of the vesicle it becomes surrounded by several layers of cells resulting from the division of the epithelial lining cells. These become thick walled and soon break away from the surrounding tissues of the cortex, so that older vesicles

can be detached (*figs. 12* and *13*, *e*). Cross sections of one of these vesicles shows an inner thin walled layer of cells (*fig. 13*, *s*), surrounded by 4 to 10 layers of strengthing cells, which are elongated or stretched in the peripheral direction (*fig. 13*, *d*).

Secondary cortex (*inner bark*).— The medullary rays of the secondary cortex are composed of starch and protein conducting cells. The protein conducting cells are best seen in radial sections, where they form one layer on each side of the medullary ray. They are analogous to the protein conducting bast parenchyma of many conifers. The starch conducting cells occupy the central part of the ray.

The bast parenchyma cells are placed end to end in single isolated rows. Their cells are about 2 to 3 times as long as wide. The greater number are secretion reservoirs for tannin and calcium oxalate. Usually only one peripheral row of bast parenchyma cells is formed each year.

Bast fibers are absent in species of Abies and in the Abietineæ Many of the bast parenchyma cells become thickened and sclerenchymatic. Like the sclerenchyma cells of the primary cortex they often branch. They are usually found in groups or nests extending the whole length of the internode.

The remaining and by far the greater portion of the secondary cortex is made up of the sieve tubes. They are arranged in radial rows and, as in all conifers, have their sieve plates on their lateral walls. No vertical or horizontal resin canals are present.

Wood.— The medullary rays are composed of starch conducting or normal pith cells only. The protein conducting cells present in the rays of the secondary cortex are wanting. As in all conifers, the tracheids of the spring wood have larger lumina than the tracheids of the fall wood. No resin canals are present in the normal wood.

Pith.— The pith adjoining the pith septum on its under side differs from the internodal pith in that it is composed of a mass of loose cells, which break away from the septum, so that in two-year old and older internodes a cavity is formed immedi-

ately below the pith diaphragm. The greater number of these cells remain thin walled. Isolated cells often become thickened but not sclerenchymatic.

The internodal pith is made up of thin walled parenchyma cells and areas of sclerenchyma. The parenchyma cells are from 2 to 4 times as long as wide. They are polygonal in cross sections and rectangular in longitudinal sections. Isolated parenchyma cells often become thick walled in older internodes. The sclerenchyma cells are cubical and smaller than the parenchyma cells. They are provided with pore canals, and the thickening often extends inward so that the whole cell lumen disappears. The cells are arranged in definite areas extending from the periphery of the pith toward the center. Many of the sclerenchyma areas extend across the pith, thus forming a kind of diaphragm of mechanical tissue which alternates with areas of thin walled parenchyma.

2. *Diseased shoots and branches.* — The normal terminal shoots differ from the lateral, not only in that they are negatively geotropic, but also in the greater or less development of their different morphological units. The diseased shoots in many respects have characters similar to the normal terminal shoots. In comparing, therefore, the anatomy and morphology of the diseased shoots with the normal, the terminal shoots should also be considered. Hartmann[25] makes a comparison of the diseased with the lateral normal branches only of *A. pectinata*.

The affected branches, like the terminal, are negatively geotropic. Cross sections of the first year's shoots show a greater development of primary cortex and pith, while the secondary cortex and wood, in proportion to the former, are less developed, about the same as that of the lateral branches. In the second year of the diseased branches changes occur, which are more marked, especially in the increased growth of the periderm, wood and secondary cortex. The wood reaches its maximum growth during the second year. This is true of all the affected branches above the tumor. At the first point of infection the

[25] *Ibid.*, p. 35.

wood continues in its greater growth in width, producing the so-called boil or tumor. The growth in width of the secondary cortex of the tumor is greater than at any other part of the affected branches. The diseased branches have a greater diameter, but are shorter than the normal lateral branches. They have a reddish color, differing from the normal branches, which are yellowish brown. Although the diseased shoots are shorter, the number of leaves does not vary much from that of the normal.

Outer bark.—The epidermis does not vary much from the normal, except that epidermal hairs are rarely present. When present the hairs are usually only one-celled, agreeing in this respect with the terminal shoots, where epidermal hairs are absent.

The periderm is more developed. It consists of from 8 to 10 rows of cells the first year, which number is greatly increased during the second and later years, when the cork cambium gradually extends inward, and finally cuts off the primary cortex. In the tumor the cork cambium often extends as far as the secondary cortex during the first year of the infection. The cork cells are larger than the normal.

Primary cortex.—The cells of the collenchyma layer under the periderm are fewer in number, as well as less thickened. The chlorophyll parenchyma of the primary cortex contains no chlorophyll, but contains, at all seasons of the year, larger quantities of starch and tannin. More of the parenchyma cells become either thick walled or sclerenchymatous. The sclerenchyma cells branch more profusely, especially in the first year's shoot. The mucilage cells are smaller, as well as fewer, and do not increase in size with the increase in age of the branch. Fewer of the parenchyma cells contain crystals of calcium oxalate, but the number of tannin cells is greatly increased.

The resin canals are present in greater numbers, and vary more in their size and form, as well as in the number and size of their epithelial cells. The second layer of cells is less thickened. Since the growth of the periderm is greatly increased, and the formation of cork layers begins earlier in the affected

branches, even in the two-year old branches, it is evident that the resin canals are soon cut off by the cork cambium, and on drying become functionless. As in the normal, the resin canals are filled up by the ingrowing epithelial or surrounding parenchyma cells. This may occur in one part of the canal only, causing the formation of resin vesicles in the part where tylosis has not begun. The vesicles originate in the same way as in the normal, by the peripheral and tangential division of the parenchymatic lining of the resin canal. The resin vesicles begin to form even in the first and second year diseased shoots, increasing in size, so that in five-year old branches vesicles or blisters are found 3 to 8^{mm} in diameter. In five-year old normal branches vesicles are seldom found more than 1^{mm} in diameter. The increase in size and number, as well as the earlier formation of the resin vesicles of the affected branches, is due mainly to the earlier formation of cork layers and the greater resin secretion. On account of the increased growth of the bark of the tumor, the witch broom vesicles not only reach their largest size here, but they dry up and become functionless sooner than in any other of the diseased branches above the tumor. Since the primary cortex of the tumor is earlier affected, dries up, and is cut off by cork layers, the resin canal communication between the diseased branches above, and the normal branch below the tumor, is cut off or closed, even during the first or second year of the infection.

Secondary cortex.—The secondary cortex contains fewer sieve tubes, which are also smaller, often only one-half as long and broad as the normal. The radial walls are provided with fewer sieve plates. The sieve plates vary in size, but are usually smaller and more irregularly distributed. Fewer branching, bast fiber-like, sclerenchyma cells are present than in the normal. The protein conducting cells of the medullary rays are absent in the diseased bast of *Abies balsamea*. The bast parenchyma cells are larger and more numerous, and are usually filled with calcium oxalate and tannin.

Wood.—The growth of the wood in the diseased annual rings

does not vary greatly from that of the normal. The width of the wood cylinder in one year shoots above the tumor is about equal to that of the normal. The second, third, and fourth rings, however, are wider than the normal. The tracheids of the diseased wood are thicker walled. The annual rings of the affected branches are always more irregular in their width, and are often ten times as wide on one side as on the other. This may occur in one ring only, the following or preceding rings being equally thickened throughout. This unequal radial width of some rings is due to disturbances in the direction of the growth of the shoot that year. On account of the increased growth of the wood and bark, as well as the increased number of branches, the weight of the witch broom increases with its age, and more rapidly than the normal branches. The growth of the healthy part of the witch broom branch below the tumor is also less than in the normal ones. This part of the branch is, therefore, less able to bear the weight of the heavier affected part, and the witch broom becomes suspended, changing its position or falling on one side. The affected branches, which are all negatively geotropic, assume during the next season their erect growth by curving upward. On the convex side thus formed there occurs an increased growth, not only in the width of the annual ring, but the tracheids are thicker walled, rounded, and are separated by intercellular spaces, characteristic of all regulatory tissue formed in the wood of coniferous trees as a result of resistance to mechanical forces.[26] Although the annual rings in the affected branches are as wide and often wider than the normal, they still contain fewer tracheids per square unit of surface area. This is due to the fact that in the diseased branches more medullary rays are formed, often twice the number that are formed in the normal wood.

Resin canals, which are absent in the normal wood of *A. balsamea*, are always present in the wood of the tumor, and are nearly always present in the wood of older diseased branches

[26] HARTIG, R.: Den anatomischen Bau des Rothholzes. Forst.-naturw. Zeitsch. —: 163. 1896.

TABLE V.

SHOWING NUMBER AND DISTRIBUTION OF THE VERTICAL RESIN CANALS IN THE DISEASED WOOD OF A. BALSAMEA.

Cross sections		Number of resin canals in annual rings. Annual rings arranged from bark toward pith[27]																					Diameter of resin canals μ	Remarks
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Healthy part below the tumor.	I. 6cm below the base of the tumor.																							No resin canals present.
	II. 1cm below the base of the tumor.																							
	III. At the base of the tumor.	11	40	5																			12–25	Mostly endings of resin canals.
	IV. 1cm above the base of the tumor.	40	56	53	49	30	27	21	2														16–56	Canals usually found in the spring wood. The peripheral rings of the tumor are narrower and contain fewer canals. With the increase in age of the tumor there is a corresponding decrease in the number of resin canals of the annual rings; but with the increase in age of the diseased branches an increase in the number of resin canals formed takes place.
Boil or tumor.	V. 4cm above the base of the tumor.	18	30	39	47	84	111	104	120	105	95	58											21–55	
	VI. Middle of the tumor.	10	17	13	8	11	15	21	30	45	60	44	25	26	60	77	58	47	15	8[28]			24–60	
	VII. 1cm below the apex of the tumor.	9	6	17	30	56	50	36	28	15	11	8	6										18–50	
Diseased branches growing from the tumor.	VIII. Base of an 18-year-old branch.					4		6	19	21	26	4	3	2	5	4								
	IX. 4cm above base of branch VIII.							9	13	18	11	6	8		5	6								
	X. 10cm above base of branch VIII.						7	10	16	4	7	5		8	10	9								
	XI. 20cm above base of branch VIII.	14	11	8	4																		10–35	
	XII. 1cm above base of a side shoot of branch VIII.					8	4	12	9	8	11	6	4	3	5									
	XIII. 10cm above base of shoot XII.													5	8									
	XIV. 9-year-old branch 40cm above tumor.					3	5	4																

[27] By arranging the annual rings from the bark toward the pith all rings that grew the same year will fall in the same column.

[28] Year of the infection.

TABLE VI.

SHOWING NUMBER AND DISTRIBUTION OF THE VERTICAL RESIN CANALS IN THE DISEASED WOOD OF A. BALSAMEA.

Witch broom	Cross sections	Number of resin canals in the annual rings. Annual rings arranged from bark toward pith												Diameter of resin canals μ	Remarks
		1	2	3	4	5	6	7	8	9	10	11	12		
A.—With 21 diseased branches growing from an area of about 6 sq. cm. of the tumor.	I. Healthy branch 4cm below base of tumor.														No resin canals present.
	II. At the base of the tumor.	4	19											10–40	Endings of resin canals.
	III. 1cm above the base of the tumor.	20	25	15	30	12	18[29]							11–45	Mostly endings of resin canals.
	IV. Base of a 6-year old branch from tumor.														No resin canals present.
	V. 3cm above the base of branch IV.														
	VI. 10cm above the base of branch IV.														
	VII. 20cm above the base of branch IV.														
	VIII. 40cm above base of lateral branch of branch IV.														
B.—Growing from the top of the main axis of the affected tree.	I. Healthy part 12cm below base of tumor.														No resin canals present.
	II. Base of tumor.	7												8–37	Mostly endings of canals.
	III. 2cm above base of tumor.	10	16	9		4			3		4			10–40	Many of them are endings of the tumor canals.
	IV. Base of a 3-year old branch from tumor.														No canals present.
	V. Base of a 6-year old branch from tumor.														
	VI. 4cm above base of branch V.														

[29] Year of the infection.

above the tumor. The distribution and number of resin canals are given in tables V and VI.

Resin canals are never found in the healthy part of the branch below the tumor. They first appear in sections made at the base of the tumor and here only in the outer annual rings. All the resin canals of the tumor have their endings at the base, between the healthy and the diseased wood. The ends are pointed and gradually disappear between four tracheids, which in their meristematic condition probably functioned as epithelial cells. In sections made above the base of the tumor, the number of annual rings affected as well as the number of canals increases. The greatest number is found in the middle of the tumor (table V, section VI), where the canals, also reach their greatest diameter. From the middle of the tumor toward its apex the number of canals decreases, the greater number of them ending at its upper end. Many of the canals continue in the affected branches for some distance. The affected branches of some witch brooms have no canals (table VI, A., sections IV to VIII.)

Usually, however, with the increase in age of the branch, there is a corresponding increase in the number of its canals. With the increase in age of the witch broom the outer annual rings of the tumor and branches become narrower, often having only a few layers of tracheids. With this decrease in width of the annual rings, there is a corresponding decrease in the number of canals formed in the tumor; but an increase occurs in the number of canals formed in the branches (table V, sections VI and XII to XIV).

The resin canals are usually found in the spring wood, where they form a ring of canals separated only by the medullary rays (*fig. 14*). This ring of canals sometimes extends the whole distance around the annual ring. Usually, however, it extends only one-fourth to one-half of the distance, with here and there an isolated canal. Rings of canals and isolated canals are often found in the summer and fall wood. The regulatory tissue, or so-called "red wood," formed on the

convex side of recurving branches, seldom contains any resin canals.

Pith.—The diseased pith differs essentially from the normal in that its cells become thickened sooner, also forming larger groups of sclerenchyma cells. The cells of the pith area below the pith septum, which remain thin walled in the normal branches, become thickened in the diseased branches. Small areas of sclerenchyma cells are sometimes formed, which are never present in the normal. The internodal pith shows a greater development of mechanical tissue than in the normal branches. The diseased branches, which are correspondingly larger than the normal, also have a greater development of pith.

SUMMARY OF THE MOST IMPORTANT CONCLUSIONS.

Normal organs.

1. Stomata are found in greater numbers toward the tips and on the lower surfaces of the leaves of the lateral shoots. The leaves of the terminal shoots have their stomata distributed about equally on all sides.

2. Hypodermal strengthening cells are always present in the leaves. They are seldom found in cross sections made above the middle of the leaves of the lateral branches. Below the middle they are usually found isolated on the upper leaf surface and in continuous layers on the lower surface. The shorter, rigid, and terete leaves of the terminal shoots have a greater development of hypoderm.

3. The number of hypodermal strengthening cells decreases from the base toward the tip of the leaf; but with the decrease in the number of hypodermal cells there occurs a corresponding increase in the number of stomata.

4. The transfusion tissue is not as well developed in the leaves of the lateral branches as in the leaves of the terminal shoots. In the former there are two small areas, each one lying dorsal to the outer half of the two phloem areas. In the leaves of the terminal shoots the two transfusion tissue areas have

united and formed one large area on the dorsal side of the phloem and pericycle beneath the endodermis.

5. No epidermal hairs are present on the bud scales. All the scales are fringed with thin walled, hypha-like, marginal hairs, through which the resin diffuses to the exterior of the scales, until the bud is covered with a layer of resin sufficiently thick to prevent any further transpiration of moisture and exudation of resin.

6. Resin canals are usually present in all of the bud scales. Cross sections of many scales show from two to six resin canals.

7. The terminal or leader shoots, have no epidermal hairs. Epidermal hairs are present only on the one to three-year old lateral shoots.

8. Resin vesicles or blisters are formed only in the primary cortex and in those parts of the original resin canals which have not been disturbed by the unequal peripheral growth of the bark, cork cambium, and the formation of tyloses. The vesicles originate and increase in size by the radial and tangential division of the lining cells of the undisturbed part of the resin canal.

9. The normal wood of *A. balsamea* contains no resin canals.

Diseased organs.

10. Fewer stomata are present on the diseased leaves, and their distribution is similar to that of the normal.

11. Hypodermal strengthening cells are present, especially in the basal half of the leaf; they are more irregular in their form and size; and are often found in nests and groups.

12. The transfusion tissue is nearly always present, often in one to three small areas on the dorsal side of the phloem. The cells of the diseased transfusion tissue usually have simple as well as bordered pits.

13. The diseased buds are covered over with a greater number of bud scales, which are smaller than the normal. The diseased scales, like the normal, are fringed with marginal hairs and the buds are resin covered in winter.

14. Fewer of the diseased scales have resin canals; more than two canals are never present.

15. Epidermal hairs are rarely present on the diseased shoots. When present they are usually only one-celled.

16. Resin vesicles begin to form even in the first and second year diseased shoots. They increase in size so that in five-year old branches vesicles or blisters are found 3 to 8^{mm} in diameter. In five-year old normal branches vesicles are never found more than 1^{mm} in diameter.

17. Resin canals are always present in the wood of the tumor, and are nearly always present in the wood of older diseased branches above the tumor. The canals are usually found in the spring wood. With the increase in age of the tumor, there is a corresponding decrease in the number of resin canals of the annual rings, but with the increase in age of the diseased branches an increase in the number of resin canals of the annual rings takes place.

In conclusion, I wish to state that I am indebted to Director William Trelease and to the other officers of the Missouri Botanical Gardens for the use of their libraries and laboratories, and for kindly supplying facilities which have made it possible to do the work here presented.

MISSOURI BOTANICAL GARDEN.

EXPLANATION OF PLATES XIV AND XV.

FIG. 1. Cross section of a normal leaf 4^{mm} above its base, showing epidermal and hypodermal cells.

FIG. 2. Cross section of a normal leaf, showing the non-pitted, lignified parenchyma of the pericycle, bounded on its dorsal side by the endodermis.

FIG. 3. Cross section of a normal leaf, showing one of the two areas of transfusion tissue.

FIG. 4. Cross section of a diseased leaf, 4^{mm} above its base, showing the epidermal and hypodermal cells.

FIG. 5. Cross section of a diseased leaf, showing two areas of transfusion tissue: *a*, non-pitted, lignified parenchyma; *b*, bordered pits; *s*, simple pits.

FIG. 6. Section of diseased leaf, showing non-pitted, lignified parenchyma. Same magnification as in *fig. 2*.

FIG. 7. One of the outer and exposed normal bud scales, fringed with the marginal hairs, which are thin walled and filled with resin.

FIG. 8. Cross section of a normal bud scale with four resin canals.

FIG. 9. Cross section of a normal bud scale with two resin canals.

FIG. 10. Longitudinal section at the base of a bud of a normal shoot: *a*, cambium, with phloem and xylem cells; *b*, base of the annulus, or wall of the cup, surrounding the growing point in winter; *c*, base of the inner bud scales, composed of thick walled collenchymatous cells, similar to those of the annulus and pith septum; *d*, parenchyma of the primary cortex; *e*, part of pith septum, with irregular 3–4-sided prismatic cells; *f*, pith cells; *g*, loosely connected rounded pith cells, which break away from the septum in older internodes, forming the pith chamber.

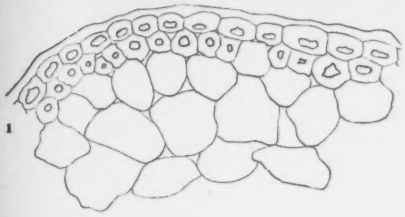
FIG. 11. Epidermal hairs on a normal one year old lateral shoot.

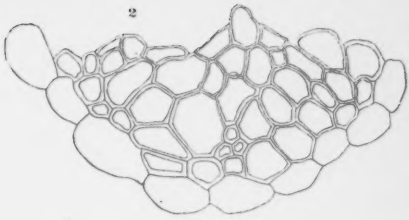
FIG. 12. One of the detached resin vesicles of the primary cortex, magnified about four diameters: *a*, remnant of the original resin canal from which the resin vesicle developed.

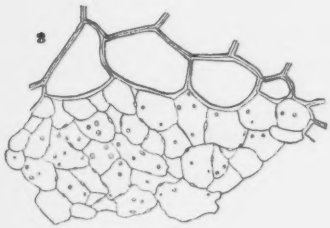
FIG. 13. Cross section of the thin membrane covering the resin vesicle: *a*, thick walled, elongated or stretched cells of the membrane; *s*, thin walled epithelial cells lining the membrane of the vesicle on the inside; *b*, one of the epithelial cells dividing radially; *c*, one of the epithelial cells dividing tangentially; *d*, primary cortex; *e*, parenchyma cells of the primary cortex torn loose from the resin vesicle membrane, which has elongated or increased in size peripherally.

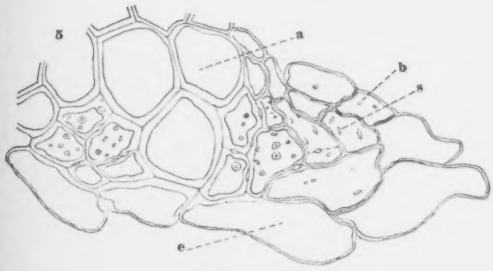
FIG. 14. Cross section of the wood of a diseased branch about 1^{cm} below the middle of the tumor, showing two abnormal vertical resin canals: *a*, an in-grown epithelial cell, filling up almost the entire lumen of the resin canal (tylosis).

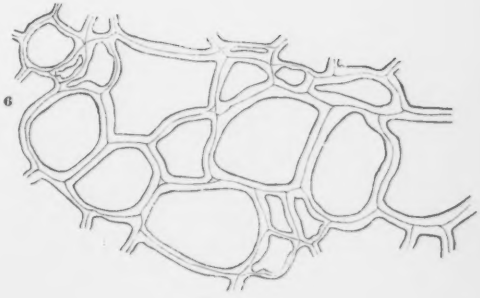
PLATE XIV.

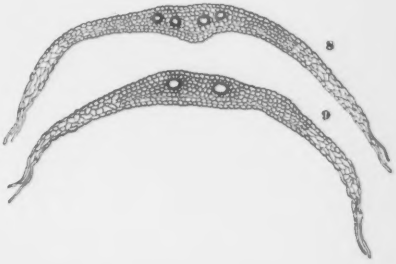


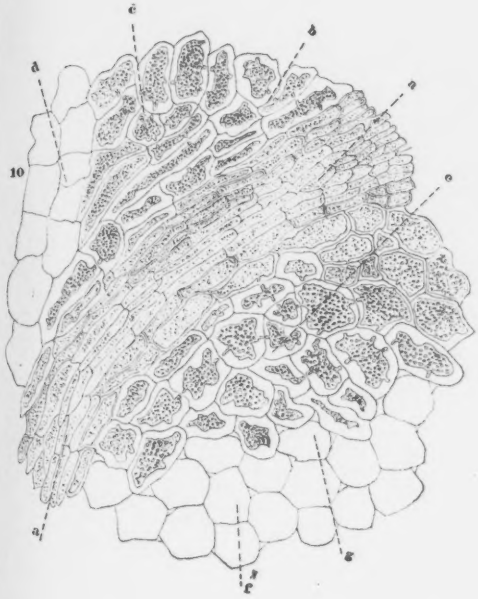


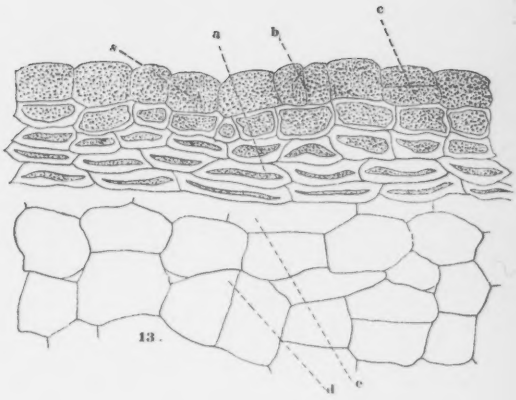


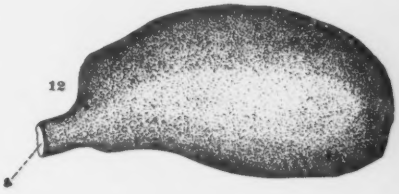


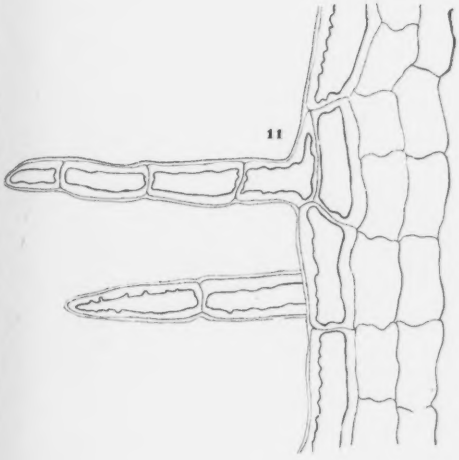


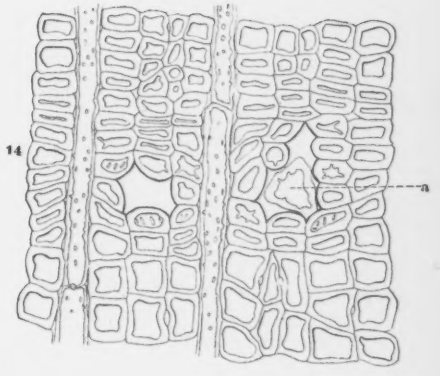












ANDERSON on ABIES AFFECTED by ÆCIDIUM.

THE PUBLIC GARDENS AND PLANTATIONS OF JAMAICA.[1]

WILLIAM FAWCETT.

INTRODUCTION.

JAMAICA is about ninety miles south of Cuba. Its most western point is nearly directly south of Toronto, as it lies between 78° 20′ 50″ and 76° 11′ W. long. It is situated between 18° 32′ and 17° 43′ N. lat., so that it is only one to two degrees nearer the equator than the City of Mexico (19° 25′), and a little farther from the equator than Belize. It is a very small island, being only 144 miles long and forty-nine miles wide in its broadest part; its area amounts only to 4,207 square miles, of which very little is flat, and a great deal is not suitable for cultivation.

The aboriginal name of Jamaica was Xaymaca, denoting "a land covered with wood, and watered by shaded rivulets." The character expressed by the name is what one might expect to find in an island with lofty mountains, its shores bathed by the Gulf stream, and lying in the path of the trade winds. The general trend of the mountain ranges being at an angle to the direction of the prevailing winds, there is considerable precipitation nearly all the year round in some parts, while in other districts a small amount of rain falls during a few days only in two months of the year.

The general features of the landscape and of the flora which clothes it have been developed by the position of the island, and its geological history. The lowest strata containing fossils are the Hippurite limestone of the Cretaceous series. Below this there is a series of metamorphosed shale, sandstone and conglomerate, with dikes of intrusive diorite, syenite and granite.

[1] Prepared for the Botanical Society of America, Toronto meeting.

Above the Hippurite limestone are beds of black shale, 1000 feet in thickness, overlaid by a trappean series, all of which are placed by Sawkins in the Eocene age. Then follow the yellow limestone of Miocene times, white limestone of very recent age, and marl, coast lime, and alluvium of post Tertiary times.

The differences in elevation from sea level to the 7423 feet of the Peak, the various exposures to sunlight, the abundance or the want of rain and dew, the geological formations, all have their influences on plant life, and make the conditions of existence of the most diversified character, and the cultivation of economic plants from all parts of the world an easier task than in most other places.

HISTORY OF THE GARDENS.

The first botanic garden in Jamaica was formed about 150 years ago by a private individual, Mr. Hinton East, on his property near the present village of Gordon Town, nine miles from Kingston. After it had been in existence for some years, in 1774 Sir Basil Keith became governor, and determined on the formation of two government botanic gardens, one a "European garden," and the other a "Tropical garden." In December of the same year a committee of the legislature recommended that £700 be appropiated for the purchase of a piece of land proper for a botanic garden, and that £300 sterling be provided for the annual salary of a botanist.

In 1775 a property named Endfield, adjoining Mr. East's garden, was purchased and Dr. Thomas Clarke came out "at the particular instance and request" of Sir Basil Keith, as island botanist, and to take charge of the gardens. Dr. Clarke introduced in 1775 the China tea plant, camphor, litchi, *Cycas circinalis* (the "sago palm"), and *Desmodium gyrans*; in 1778 *Blighia sapida* (Akee); and in 1779 the clove tree. Endfield being a "steep hillside" proved unsuitable, and in 1778 a law was passed to purchase land for a botanic garden at or near Bath. The botanic garden at Bath was founded in 1779 and placed under the care of Dr. Thomas Clarke.

In June 1782 Captain Marshall, of H. M. S. Flora, one of Lord Rodney's squadron, captured a French ship bound from Mauritius for Haiti, carrying a number of plants of economic value. The ship was sent as a prize to Jamaica, and Captain Marshall "with Lord Rodney's approbation" deposited the whole collection in Mr. East's garden. Many plants were new introductions, and amongst these were the mango, cinnamon, and jack fruit.

On Mr. East's death in 1790, the Liguanea garden was offered by his nephew to the assembly as a public garden at their own price. It was purchased under the authority of an act of the Assembly, the preamble stating that the garden in Bath was insufficient in extent, and was besides liable to be carried away by the river which had destroyed two-thirds of the town.

In 1793 Captain Bligh in H. M. S. Providence brought several hundred plants of the breadfruit and other valuable plants from Otaheite for the West Indies. These were distributed to the gardens at Liguanea and Bath, and to other centers, and committees were appointed to make arrangements for their reception, the care of them, and their distribution. One of the gardeners, James Wiles, who had circumnavigated the globe with Captain Bligh, was appointed to the care of the Liguanea garden, and writing to Sir J. Banks in 1793, he says:

> All the trees under my charge are thriving with the greatest luxuriance. Some of the breadfruit are upwards of eleven feet high, and my success in cultivating them has exceeded my most sanguine expectations. The cinnamon tree is become very common, and mangoes are in such plenty as to be planted in the negro grounds.

In 1782 Dr. Thomas Dancer was elected physician of the Bath of St. Thomas the Apostle; in 1788 he was appointed by the legislature superintendent of the Bath garden; and in 1797 island botanist. The duties of the island botanist were defined as follows:

> To collect, class, and describe the native plants of the island; to use his endeavors to find out their medicinal virtues; to discover if they possess any qualities useful to the arts, and annually to furnish the House with a correct list of such plants as are in the botanic gardens, together with such information as he may have acquired relative to their uses and virtues.

In 1799 Dr. Dancer went to practice in Kingston. He made the medicinal plants of the island a special study, and published in 1801 "The medical assistant, or Jamaica practice of physic." He died in 1811.

The colony had now to undergo a period of difficulty and distress, as the slave trade was abolished in 1807 without compensation to the planters, and the wars with France and the United States caused great depression. Accordingly in 1810 the Liguanea garden was sold, and that at Bath was never afterwards adequately supported.

In 1825 Dr. Jas. MacFadyen was appointed island botanist. In 1837 appeared the first volume of his *Flora of Jamaica*; in 1850 part of the second volume was printed, and this was all that was published. He did not retain his appointment long; and in 1828 Thomas Higson was appointed island botanist and curator of the botanic garden at Bath. He presented to the garden a collection of living plants collected by himself in South America.

In 1829 the garden at Bath, of one and three-fourths acres, was increased by three acres to the west. Higson left Bath in 1832; and in 1846 Nathaniel Wilson was appointed island botanist with the care of Bath garden. Wilson had been in the gardens at Kew and at Kensington for several years, and was a most capable man. He kept up a correspondence with Sir W. J. Hooker, director of Kew gardens, and introduced a very large number of plants from Kew and other parts of the world, trusting to be repaid his expenditure by the liberality of the assembly. *Bœhmeria nivea* was imported by him, and he formed a very extensive collection of fiber plants. He also received from Kew in 1846 and 1847 the mangosteen, litchi, durian, and *Musa Cavendishii*. In 1849–1850 he reports the arrival of Poinciana, Spathodea, *Bougainvillea spectabilis*, *Cæsalpinia Sappan*, Amherstia, and Assam tea.

In 1851 there was some intention of moving the site of the garden elsewhere, and Wilson, referring to Bath, says in his report for that year:

I would most unhesitatingly say that a more congenial climate for the growth and propagation of plants is not to be met with in the island. The humidity of the atmosphere is proverbial and suitable to a peculiar degree for plants in general.

In 1856 the Sulphur river inundated the garden for the fifth time since 1848 and destroyed half an acre. These floods and the impossibility of extending the garden for the growth of additional plants were constant difficulties with Wilson, and in 1858 he says:

The attention of the executive has of late been pointedly directed towards it [the garden] with a view not only to place the establishment on a scale of permanent efficiency, but in a more central locality, accessible from all parts of the island . . . . The want of a more central and extensive depot has long been felt, particularly at the west end and north side of the island, where distance renders it impracticable to convey plants safely, and where industrial institutions and experimental gardens are springing up.

In 1860 the legislature appropriated money for the purchase of Castleton, and Wilson was entrusted with the formation of a garden there, on the understanding, however, that the garden at Bath was to be maintained for supply of seeds to Castleton, and plants for general distribution. In his report for 1861, he states that Sir W. J. Hooker had sent out the previous year seeds of *Cinchona succirubra*, *C. nitida*, and *C. micrantha*, and that several hundred plants were ready for planting out. At this time the market price for succirubra bark was 6s. per lb. In 1862–63 an assistant to Mr. Wilson was appointed, Mr. Robert Thomson, and the formation of the garden at Castleton was commenced.

Experiments were made in planting out cinchona in different parts of the Blue mountains, and at length in 1868, during the governorship of Sir John Peter Grant, the cinchona plantations were started under Mr. Thomson as "superintendent of botanic gardens" in succession to Mr. Wilson.

Six hundred acres of virgin forest land were assigned for planting cinchona by Sir J. P. Grant on the southern slopes of the Blue mountains, ranging from 4000 to 6000 feet above sea level, and a commencement of work was made in the same year

(1868) by planting out forty acres with five species of cinchona. Now also a first beginning was about to be made to realize the conception of Sir Basil Keith of nearly a hundred years before to have a "European garden" in a temperate climate. A small plantation was made in 1869 of Assam tea, and afterwards of a hybrid between the Assam and China. *Eucalyptus globulus* from Australia, *Cupressus macrocarpa* and *Pinus insignis* from California, and *Pinus excelsa* from the Himalayas are among the forest trees planted out and flourishing in later years. In 1869, 40,000 plants of cinchona were offered for sale at rates of £5 to £7 per 1000.

At Castleton, up to 1869, there had been no general importation of plants, because of doubts about maintaining the garden on account of its distance from Kingston. In the Blue Book for 1871 Sir J. P. Grant says:

> The famous Jamaica botanic garden of ancient times, which was not only of the highest intrinsic value, but also was admirably situated, was sold, I believe, for a trifle, and was broken up a long time ago, in some spasmodic fit of false economy. More lately a botanic garden was established at Bath. The site was unfortunately selected, being a long day's journey from the capital. But the purchase, in 1859, of Castleton, and its formation in 1863 into a new botanic garden in substitution for the garden at Bath, which was finally abandoned in 1866, is said to have been determined upon because of serious damage caused and threatened by a water course. The selection of Castleton as the site of the new garden was also unfortunate, as it is a distance of nineteen miles from Kingston; and it is important to interest the public as much as possible in such an institution as a botanic garden. But the selection having been made, and a large number of plants having been established there, whilst the position, except in respect of its distance from the capital, is unexceptionable, it would have been unwise once more to have thrown away all that our predecessors had done for us by removal to a fourth position. It was determined therefore to treat the Castleton garden as a fixture; and as it is not too far from Kingston for a holiday excursion, to go to some little expense in its gradual embellishment, in the hope of attracting visitors to what I believe will certainly become one of the most interesting spots in the West Indies.

As soon as this determination had been arrived at in 1869, Dr. (now Sir) J. D. Hooker sent out from Kew great numbers of

new and valuable plants, 400 different species and varieties, among which were mangosteen, Brazil nut, bhel, *Monstera deliciosa*, carob bean, coca, Tonquin bean, teak, New Zealand flax, and thirty-two species of palms. In the same year two cases of grafted mangoes arrived from India *via* Kew; Mr. Thomson states that "to His Excellency the Governor, from his personal knowledge of Indian mangoes, we are obliged for their introduction." Even at this early period of its existence the nutmeg trees began to bear fruit, and the clove trees were six feet high.

In the same Blue Book quoted above, Sir J. P. Grant reports that a gardener had been obtained from Kew to reside at Castleton, as Mr. Thomson had taken up his residence at the cinchona plantations thirty-four miles off, in the Blue mountains. He took charge at Castleton in December 1870.

> Upwards of 200 species of plants new to the island were introduced during the year. Among these perhaps the most interesting were two plants of Ipecacuanha, two true mangosteens, and five choice varieties of pine apple; also four noted Bombay grafted mangoes, imported two years ago, are very flourishing, some of them being already five feet high. My belief is that there is nothing to prevent Jamaica becoming, for the quality, variety, and commercial value of its fruit, the most noted spot in the world, when gardening shall be understood, and the value of the art shall be duly recognized here.

In 1870, four varieties of orange were imported, viz., navel, St. Michaels, tangerine, and mandarin. In after years thousands of grafted plants of this St. Michaels, and seedlings also of the tangerine and mandarin were distributed all over the island. A large tank was made for the cultivation of the *Victoria regia*, which has been growing there ever since.

This was a period of great importance in the history of the development of the public gardens. In 1868 the government undertook to plant out in cocoanuts the narrow sandy strip of land, known as the Palisades, with Port Royal at one end, forming a natural breakwater for the magnificent harbor of Kingston. The first clearing and planting was done early in 1869, and by 1879 nearly 20,000 cocoanut palms had been planted out, and 700 of them were bearing fruit. In 1870, £1800 was voted for

the establishment of a garden in the Parade square of Kingston, and in 1871 £2267 were voted for continuation of the work. This sterile waste in the center of the city about seven acres in extent, Mr. Thomson reports in 1871, was enclosed with a handsome iron railing. In 1871 the governor ordered that:

> In an appropriate quarter of the garden at Castleton space should be reserved for every species of cane procurable, so as, if possible, to afford specimens of every true, distinct, and permanent variety known. The botanical garden of Jamaica should not be behind any garden in the world in regard to specimens of this particular sort of plant.

The governor applied to Mauritius and Martinique for specimens of all varieties of cane grown there. Over sixty varieties of sugar cane were received in 1872 and 1873 from Mauritius, and the salangore from Martinique.

In Sir J. P. Grant's report in the Blue Book for 1871, published in the *Gazette*, October 1872, he says:

> The Bombay grafted mangoes, planted three years ago, are in a thriving condition, and from eight to nine feet high. I do not doubt that the finest varieties of this almost unequalled fruit will thrive here quite as well as at Bombay. The plant has naturalized itself here in the course of only ninety years, and now spreads itself self-sown over large tracts in all parts of the island. As the propagation has been exclusively from seed, it is surprising to find amongst these wild trees so many bearing fruit at all eatable, which I think could not be the case were not the climate and soil very propitious for this plant. The quantity of fruit produced is remarkable, and it is greedily devoured by horses, cattle, and swine. With vessels running in six days to New York, the commercial value of an orchard of fine Bombay mangoes near Kingston would surely be very great.

Mr. Thomson in his report for 1873, referring to these mango trees, points out that:

> Although the climate of Castleton is extremely favorable for the growth of these plants, the reverse is the case so far as the production of fruit is concerned. As soon as possible, however, a small plantation of these varieties will be established at the proposed garden at Hope, which, with its far drier climate, is probably as good a locality as any in the West Indies for the production of this fruit.

In 1873, the report of the gardens states:

Arrangements have been made to commence operations at Hope, with the view of establishing a pleasure garden and a small sugar cane farm for experimenting upon new varieties of canes. The climate of the Castleton garden is too humid for numerous species of plants, which will find a congenial home in the drier climate of the Liguanea. . . . . The establishment of this garden, simultaneously with that on the parade, coupled with the greatly increased command of water in the course of being brought to Kingston, must undoubtedly constitute a new era in the history of horticulture in Jamaica.

It was found advisable to secure the services of a skilled European gardener at Cinchona. Accordingly Mr. Nock arrived here in April 1874, from Kew gardens. He devoted attention to the cultivation of European vegetables, which he hoped to show may be successfully grown in great abundance and variety under our conditions of climate. Mr. Thomson says in 1875 that:

Mr. Nock has been very successful in producing an assortment of vegetables such as are not grown elsewhere in the island. It is to be hoped that the peasantry will initiate the cultivation of similar vegetables, as these experiments show that at this height (5000 feet above the sea) almost all European vegetables can be grown with advantage.

These hopes have been fulfilled, for the peasantry now grow all kinds of "English" vegetables in the Hill gardens district.

In 1876 a plantation of Liberian coffee was established at Castleton. With reference to the "Hope experimental grounds," Mr. Thompson wrote:

It is about three years since the government obtained possession of upwards of 200 acres of Hope land, contiguous to, and for the most part under the level of the Hope reservoirs. The acquisition of this land afforded an excellent opportunity for experimenting upon the numerous new varieties of canes that had just been imported from the Mauritius botanic garden. While this matter was under consideration, it was also proposed that the beautifully situated land in question should be utilized in a variety of ways. Among other schemes it was proposed that, in consideration of the accessibility of this locality to Kingston, a pleasure garden should be formed for the inhabitants of that city.

But the want of water prevented anything more being done than planting out a few canes, and forming a small nursery.

The collection of new sugar canes, embracing some sixty varieties of new

canes, imported a few years ago from the Mauritius botanic garden, was in the first place established at Castleton garden. As the necessary scope and appliances at Castleton for the experimental cultivation of these canes on a sufficiently large scale were not obtainable, advantage was taken of the government land at Hope to carry out the necessary experiments. Accordingly in 1874 the first batch of canes, consisting of eighteen varieties, was transferred to Hope and planted to the extent of nearly an acre each. In 1875 the remaining varieties at Castleton, numbering upwards of forty, were removed to Hope, and there planted in small plots in order to ensure a command of cuttings for subsequent propagation, the area occupied by these being about five acres.

But water failed often and there was disappointment. Some fifty plants of teak were set out at Hope in 1874, and 500 plants more in 1875. About ten acres were thus planted with teak.

Mr. Thomson retired on pension in 1878, and in December 1879 the gardens and plantations were constituted a department under Mr. Daniel Morris as director. The management of the gardens and grounds attached to Kings house, the residence of the governor, was now placed under the department. Dr. Morris, in his report for 1885, refers to the future development of Hope nurseries.

> The only drawback to this locality as a site of a botanic garden is the smallness and precarious nature of the water supply. . . . . Although sufficient for the nursuries this water supply is wholly inadequate to maintain a large area, such as a botanic garden must necessarily be, under perpetual cultivation, unless a system of reservoirs and tanks were introduced for the storage of water.
>
> The Hope plantation might, however, be greatly extended in the direction of growing and distributing economic plants, and in this respect the establishment would prove of great service to the island. As circumstances permit, this work will be transferred as much as possible from Castleton, leaving the latter to supply only the districts in communication with the main trunk road and the north side.
>
> The lands adjoining the Hope nurseries, about 100 acres in extent, might be cleared and laid out as a public park, with grass lawns and shade trees, and afford a convenient and healthful resort for the inhabitants of Kingston and Half Way Tree. At present, persons driving along any of the hot, dusty, and dreary looking roads leading out of Kingston have no place where they could get out of their carriages and enjoy a walk under shade. With the exception of the Parade garden, Kingston, which is largely fre-

quented by the poorer classes of people residing in the immediate vicinity, there is no place of the nature of a park in the island. In the neighborhood of every tropical city it is very necessary to have a public park provided with seats and ample shade trees where the people can for a time, at least, escape from the heat, and glare, and dust, and where they come into contact with some of the fresh invigorating influences of nature.

The cost of laying out a park at Hope in conjunction with the experimental cultivation of fruit trees and nurseries of economic plants would be about £4,000 to £5,000.

The governor, Sir Henry Norman, commenting upon this view of the future of Hope, wrote:

As regards the Castleton and Hope nursery gardens, it will be seen that there is a tendency rather to increase the usefulness of the latter than the former, and considering the inconvenient situation of Castleton this seems right. Measures may be taken from time to time to improve the Hope gardens, but I am not prepared to recommend outlay from public funds for the construction of a park at the Hope. It is situated five miles from Kingston, which is too great a distance to allow of the poorer classes of the population enjoying the benefits of the proposed park.

The scheme proposed now to connect Kingston and Hope gardens by an electric tramway with cheap fares removes the objection that the poorer classes of Kingston would not be able to make use of it.

Dr. Morris left Jamaica in March 1886 to take up an appointment as assistant director of Kew gardens. Sir H. Norman then referred to a committee of the legislature the consideration of the condition of the department, and the provision to be made for its maintenance in the future. The committee submitted a report, which was adopted by the council in October 1886. In it the committee state that they

Fully recognize the importance to a purely agricultural colony of an organized department for the giving of reliable and authoritative information in matters of agriculture and cultivation and for the dissemination of such knowledge. The importance of this is specially enhanced at the present time when the depressed condition of our staple products in the markets of the world suggests not only the application of all means of science and invention to their more perfect and more economical production, but also the encouragement of the cultivation of those so-called minor products for which

the soil and climate of this island are so fortunately suited. Courage may be taken from the experience of Ceylon, where the effects of the failure of its great staple of coffee have in a few years been largely diminished by attention to the cultivation of tea, cocoa, and other products, which has been materially benefited by the interest and fostering care of the botanical department of that island. The influence of a trained and scientific chief over such a department must be felt as well in the interchange and in the consequent continuous and careful thought of the information and experience of old and practical planters and cultivators, as in the education and training of the younger and inexperienced, and in the intelligent and profitable application of means and labor of both peasant and proprietor, to present and to new objects of cultivation.

The work of the gardens department, its chief aims and possibilities, have frequently been brought before the public of Jamaica in the present director's annual reports. Thus in 1892 occurs the following:

The two main divisions under which work in a colonial botanical department may be classed are: first, the supply of plants yielding products new to the agriculture of the colony, or of a better kind, or such as are not readily obtainable otherwise, involving experimental and nursery grounds in such situations as are suitable; second, the providing of information regarding the kind of soil, climate, etc., fitted for the plants, their proper cultivation and preparation for the markets. The second division is most economically and effectively carried on by means of printed matter combined with correspondence; but practical demonstrations of methods in the gardens are advisable whenever they can be carried out. Both divisions imply considerable correspondence with persons in other countries as well as a complete herbarium and a good library.

During the past twelve and one-half years, from the time that Mr. Morris was first made director, to March 31, 1892, about 220,000 plants have been distributed from Castleton alone, besides seeds which would produce at least as many plants. This gives an average for a year of 17,600 plants, and includes those sent to Hope for distribution from that center.

Of those plants, about half the number were such as may be termed strictly "economic," such as cocoa, nutmeg, cloves, cinnamon, Liberian coffee, vanilla, oranges, East Indian mangoes, cardamon, kola. The remainder were palms, roses, ferns, orchids, and miscellaneous trees and shrubs, among which are included timber trees.

I stated in my report for the year 1887–8 that although it was not the mission of a botanic garden to undertake the work of a horticultural establishment, and supply the public with ornamental plants, I thought it right to

do as much as possible in that direction, so long as there was no probability of interfering with private enterprise.

But the danger of interfering with trade seems remote, and the demands on the part of the public are positive and increasing. There has been an annual demand for some 8000 or 10,000 ornamental plants, and even more than the department can supply with its present means. The question may sometimes arise, is the government right in fostering this demand; is it a legitimate one; is some great end served by the necessary expenditure, and the attention to the numberless details that it implies?

It appears to me that the question only needs to be stated for all intelligent persons to answer in the affirmative. Bacon recognizes a love for gardening as an index of a nation's advance in civilization, and without doubt it is an important factor in rendering that advance more easy and more certain. He says (Essay 46), "God Almighty first planted a garden, and indeed it is the purest of human pleasures. It is the greatest refreshment to the spirits of man, without which buildings and palaces are but gross handiworks; and a man shall ever see, that where ages grow to civility and elegancy men come to build stately, sooner than to garden finely; as if gardening were the greater perfection."

The plants, cuttings, and seeds, both economical and ornamental, from Castleton as well as from the other gardens, are distributed all over the island by means of the coastal steamer, the railway, and the post office.

The increase in the variety of cultural products, and the humanizing influence of ornamental plants are matters of appreciation in every part of the country from the mountain to the seacoast. Every person who obtains plants and grows them, from the sugar planter who makes trial of different varieties of cane, to the small settler who grows a nutmeg plant, is making experiments which are of direct benefit to himself and indirectly to his neighbors and to the district.

Parochial or other associations can do a great deal to help the work by meeting periodically to discuss all matters connected with agriculture. The sympathy felt between those engaged in kindred pursuits, the feeling of rivalry aroused to attain better results, the mutual aid obtained by interchanging ideas, are all most valuable in the improvement of agriculture. He who undertakes the laborious task of starting such an association in his own district, though he may find few at first to join him, yet by perseverance with even only one or two sympathizers will eventually meet with his reward. Such an association and this department can render mutual assistance to each other in many ways with results that will be of general benefit to the whole island.[2]

The great importance of Castleton as a botanic garden over the other gar-

[2] The local association work has been undertaken by the Jamaica Agricultural Society, formed in 1895.

dens may be estimated from the fact that there are some plants such as vanilla, which will only grow naturally there, and that there are others, such as roses, which can only there be successfully propagated. Castleton must therefore always be the great propagating center.

It is scarcely necessary to say anything in Jamaica about the importance generally of botanic gardens, for the need for them has been continuously recognized there for more than one hundred years. The value of those existing in Jamaica, Trinidad, and Demerara, is so evident that lately botanic gardens have been started in Antigua, Dominica, Montserrat, and St. Kitts, Nevis, among the Leeward Islands; in Grenada, St. Lucia, and St. Vincent among the Windward Islands; and still more recently in British Honduras.

The same movement is also going on in other parts of the world; for instance, botanic gardens have lately been established in Lagos, and the Gold Coast on the west coast of Africa.

Botanic gardens in the tropics do the work on the plant side of agricultural departments in temperate climates. They are in themselves experimental stations; and are much more efficient in introducing new cultural products, and in distributing plants and imparting useful information, than most agricultural departments.

The whole of the botanic gardens in the British Empire are more or less in communication with one another, exchanging seeds, publications, etc., and all look up to the Royal gardens at Kew as to their head for advice and assistance. Imperial federation is already in existence as regards the botanic gardens and their work. If any special variety of a plant or any new culture comes into notice, information and plants are sought sometimes directly from the local gardens; sometimes through Kew as the botanic gardens' clearing house. The director of Kew gardens has at his disposal the services of experts in every branch of botanical inquiry, and is always most willing to aid colonial gardens in every way. Any intricate question that arises in chemistry, in diseases of plants, in insect pests, in the value of products, etc., can be determined by reference to Kew. Colonial gardens are therefore not isolated, but are branches of an agricultural department as wide as the British Empire itself.

In 1896 the following paragraphs are found:

Although the means and the number of men at my disposal are infinitely small, as compared with the resources at the command of the government of the United States, we try to follow at a very long distance the aims and the methods adopted by them. Dr. A. C. True, the director of the office of experiment stations in the United States, has lately given a lucid exposition of the objects and work of these stations, and an extract from his bulletin will very clearly illustrate what we should always be striving after here.

Then follow extracts showing what the objects of the stations are, and details of their work:

Chemical analysis and the study of live stock are outside the limits of our sphere at the gardens, but attention is paid to nearly all the other points detailed.

Dr. True continues:

The service which the stations have rendered in promoting the education of our farmers is incalculable. Even if the station bulletins recorded only facts well known to scientists and advanced agriculturists, the influence of such a far-reaching system of popular education in agriculture must be very great. So vast a scheme of university extension has never been undertaken in any other line. The stations have also taught the farmer how to help himself.

The *Jamaica Bulletin*, which was started in a small way in 1887, appearing at irregular intervals, has now increased to a publication of twenty-four pages, appearing regularly once a month. It is sent free by post to all who ask for it, and the circulation is steadily increasing. The department, indeed, takes in some respects a wider scope than the experiment stations of the United States, for not only are practical lectures given in various parts of the island, but an agricultural elementary school is managed under its auspices, and the boys are trained in practical work in the gardens.

PARADE GARDEN.

The Parade garden was formed for the recreation of the inhabitants of the city of Kingston, the principal port of the island and the seat of government. It is about seven acres in extent, with shady lawns, lily tanks, borders of ornamental plants, and numerous palms and tropical flowering trees. It is lighted in the evenings by electric light, and a military band performs once a week. Elevation, 60 feet; annual mean temperature, 79° F.; average rainfall, 34.73 inches.

KINGS HOUSE GARDEN.

The garden and grounds around Kings house, the residence of the governor, amount in extent to 177 acres. The avenue from the entrance gate to the house is formed of the willow fig (*Ficus benjamina*), and the royal palm (*Oreodoxa regia*), with borders of ornamental shrubs and creepers, such as crotons, Hibiscus,

Acalypha, Tabernæmontana, Mussaenda, Tinnea, Bambusa, Dracaena, Musa, Bignonia, Antigonon, Stephanotis. In the garden, adjoining the house, there are orchids, ferns, palms, climbers, and ornamental plants generally, with several lawns, and a tank for nymphæas and the *Victoria regia*. Elevation, 400 feet; annual mean temperature, 78.7° F.; average rainfall, 48.51 inches.

HOPE GARDEN.

Hope garden is situated in the Liguanea plain between five and six miles from Kingston at the base of the hilly country through which the road passes for ten miles or so to the Blue mountains. The plain of Liguanea is one of the dry districts, the average annual rainfall at Hope being only 51.5 inches. Vegetation is affected not only by the want of rain, but also by the sea breezes, which in their passage across the plain become quite dry. The plain is characterized by the presence of Cactaceæ, such as various species of Cereus and Opuntia. The trees include *Prosopis juliflora* (cashaw or the mesquite of the mainland), *Guiacum officinale* (lignum vitæ), *Parkinsonia aculeata* (Jerusalem thorn). As we approach Hope, at the base of the hills the rainfall increases, from 35 inches in Kingston, and *Catalpa longissima* (the yoke wood tree), and *Pithecolobium Saman* (the guango) occur, while the Cactaceæ disappear.

The character of the flora is affected also by the soil, which is alluvial without any admixture of clay. Where limestone rock commences on the hill called Long mountain, the prevailing feature is the beautiful yellow flowered *Agave Morrisii*. The soil of the plain is very fertile when irrigation can be used, and the gardens in fact form part of the old Hope sugar estate.

From being at first a small nursery and an experimental ground for sugar cane, it has now developed into a large garden with six acres of lawns, three and one-half acres of ornamental borders, also ferneries and orchid houses; collections of roses, crotons and palms; plantations covering seven and one-half acres of sugar cane, Arabian and Liberian coffee, oranges, ginger,

tobacco, ramie, and five or six acres of teak. It is hoped that in time it may be possible to make it a geographical botanic garden with different sections for India, Australia, China, etc. Two and one-half acres are given up to the nurseries which contain about 70,000 plants, such as cocoa, nutmeg, clove, orange, vanilla, cinnamon, Liberian coffee, rubber plants, etc. It is the distributing center, and on an average 40,000 plants are sent out all over the island each year. The director has a residence, office, library, and herbarium in the garden. Elevation 600 feet; annual mean temperature 74.4° F.; average rainfall 51.54 inches.

HILL GARDEN.

The following account of the possibilities for usefulness of the Hill garden was written by me eighteen months ago. The ceremony, by His Excellency the Governor, of cutting the first sod of the new driving roads along the southern slopes of the Blue mountain range, inaugurated a new era of prosperity for a wide stretch of country from Newcastle to the Cuna-cuna pass. The only means of communication, until quite lately, in all this region from one district to another and to the sea-coast road, was by bridle paths, a terror to nervous riders and impossible for invalids. The road connecting the plain of Liguanea with Gordon Town is so short that it scarcely counts when there is now a commencement of the construction of roads which are to be 100 miles in length. The only cultivation in these mountains on a large scale has been of coffee, and this industry has been seriously hampered by the expense and difficulty of transport.

In 1868, Sir John Peter Grant with great foresight made the first attempt at another culture, one which could be carried on at higher elevations, namely of cinchona. The experiment was a complete success, for the government established the fact that cinchona could be grown in the island, and realized a sum of about £17,000 by the sale of bark. But for the very reason that the whole region was without roads, planters hesitated so long about embarking in the new industry, that the golden opportunity was lost, the price of cinchona bark fell, and

many persons lost money in the venture, whereas in Ceylon, with good roads and railways, fortunes had been made by all the pioneers.

Here in Jamaica, the loss to private individuals of large sums in cinchona planting, coinciding with the low prices for coffee and general depression in trade, led to the cry some ten years ago that the Hill garden instituted by Sir J. P. Grant had proved a failure, and should be abandoned. Fortunately this desponding wail has not been generally supported in the island, nor acceded to by the government. Six or seven years ago, Mr. Thistleton-Dyer, the director of Kew gardens, gave it as his opinion that it was quite possible that the Hill garden might again become the chief botanic garden of the island, and this prophecy, unlikely though it might have seemed to most, seems now in a fair way to become fulfilled, and to justify the faith of the few. The garden is situated about half way between Newcastle and Abbey Green, and the elevation of the government property ranges from about 3000 to 6300 feet, so that greatly varied experiments can be made in cultures requiring different altitudes.

The Hill garden, however, was not devoted solely to the cultivation of cinchona. Vegetables have been grown and instruction imparted so successfully, that all the settlers round for many miles grow such "English" vegetables as peas, cabbages, carrots, turnips, potatoes, artichokes, horse-radish, cucumbers and beets. Tea has been grown of a quality declared by London brokers to be excellent, and an order has just been received from a planter for 1000 plants. Timber trees of various kinds have been planted out and tended for years, and a knowledge gained of the capabilities of different trees for use in these hills where nearly all the valuable timber has already been cut. The nurseries at present contain some thousands of seedling trees. Fodder plants have been under experiment as well as many different kinds of economic plants, which will be taken up by planters in the near future, such, for instance, as jalap, which sells at 1s 6d per lb., orris root at 75 to 80s per cwt., China grass, a variety of ramie which can only be grown successfully in the hills, and

realizes twice the price of the tropical ramie, and fruit trees of temperate climates, and of high elevation both in the new and old worlds.

As this region is the best in the island for coffee, it is reasonable to suppose that it is the best for oranges, since the soil requirements of both are much the same. Although no tests have been made in comparing the oranges of Manchester with those grown here, many who know both, declare in favor of those grown in the Port Royal mountains where splendid fruit is produced at as high an elevation as 4100 feet.

The government has very lately established an orange experimental garden and nursery as part of the Hill garden establishment at an elevation of about 3900 feet. A large number of budded and grafted trees have been imported from Florida, and also from Rivers in England, who supplied growers in Florida and California in the early days of their groves. These are permanent stock trees, from which buds will afterwards be taken for budding on Seville and lemon stocks. Several thousand seedlings of the above stocks are being grown, also of the Jamaica sweet orange, grape fruit, tangerine and shaddock. Olives have been grown in the island for many years, but so far no fruit, or even a flower, has been produced. It is probable that this may be accounted for by their having been planted at too low an elevation. Eighty plants of the variety frantojo, which yields an excellent oil, have just been presented for trial by Lord Malcolm, of Knockalva, and these, together with others from Florida, have been put out at various elevations ranging from 3500 feet to 5500 feet.

Grape plants from Persia have been imported from California They grow on the table-lands of Persia, have a distinctive character of their own, and are very highly spoken of by travelers. They ripen early, and as they have a firm and tough skin they will probably prove serviceable for early shipping. The native grape of Jamaica, so abundant in these hills, though of no value as a fruit, may turn out to be of special worth for grafting the more tender European varieties.

These are a few of the cultures which may be taken up when roads are made. The prosperity of Jamaica will advance by leaps and bounds with the increased production rendered possible by means of communication, and a temperate climate all the year round will be available for invalids, within a few hours' drive of Kingston. But these benefits will also attract settlers from England when it becomes known that we have a Florida and a California in an island under British rule, with all the advantages of those climates and none of the disadvantages. Elevation 3000 to 6300 feet; annual mean temperature at 4900 feet is 62–67° F.; average rainfall, 105–114 inches.

CASTLETON GARDEN.

The drive from Kingston of nineteen miles, though a long one, is full of interest. The start is made in the fresh cool air of dawn; the road leads through the plain of Liguanea with a view of the hills in the distance, bright with the ever-changing hues of early daylight. Then the ascent becomes steeper, passing by settlers' groves of cocoa, coffee, and bananas, with a sprinkling of oranges, akees, sugar-cane, annatto, and yams. The road passes over the crest at an elevation of 1360 feet at Stony hill; thence down into the valley of the Wag water, with broad alluvial stretches covered with tobacco, cultivated by Cubans; along the winding river fringed with clumps of graceful bamboo plumes, and its banks hidden by masses of creepers; past the rocks by the roadside covered with ferns, mosses, the scarlet "dazzle," and the blue Jamaican "forget-me-not," until Castleton is reached, where art shows nature at its best by world-wide selection and harmonious combination.

At the principal gate stands one of the most superbly beautiful of all trees, the *Amherstia nobilis*, which, when in flower in the spring, is worth crossing the ocean to see. Further on we see *Norantea guianensis* climbing over a large tree, and brilliant with long spikes, not of flowers but of nectar-secreting bracts; *Mesua ferrea* attracting attention not so much by its large fragrant white flowers as by the red color of the young drooping

foliage; the mangosteen with its delicious fruit; the travelers' palm of Madagascar; *Araucaria excelsa* from Norfolk island. The palmetum contains specimens of 180 species of palms with great variety of graceful forms. The water lily tank is wonderfully beautiful with its surroundings of palms, bamboos, and grassy slopes, and the placid surface of bright water on which float the symmetrical leaves of red, white, and blue lilies, and the *Victoria regia* in the center, queen of the rest. From the brightness of the still lily pool we pass to the grateful shade of the ferneries with the quick stream dancing over the stones, and then on to examine the nutmeg tree, its yellow fruit splitting and displaying the "mace," a network of scarlet covering and half concealing the brown nut; the spicy clove and cinnamon trees; the climbing vanilla and black pepper; the coffee, cocoa, and kola trees; the peculiar flowers of Couroupita and Napoleona.

There is a small hotel in the grounds of the garden, open during the winter months, and as the importance of the garden has increased, a post and telegraph office and constabulary station have been lately erected. The railway station at Annotto bay is only nine or ten miles distant.

Elevation 580 feet; annual mean temperature 76–82° F.; average annual rainfall 113.15 inches.

BATH GARDEN.

The Bath garden, forty-four miles east of Kingston, is situated in one of the most tropical districts in the island. In other places, *e. g.*, in Hanover, it could easily be imagined that the road led through some English park, until we perhaps notice the sensitive plant (*Mimosa pudica*) trailing amongst the grass, or come upon a gigantic ceiba tree with buttressed trunk and its branches stretching far and wide loaded with a whole garden of exotic epiphytes. But in the Bath district the luxuriance of the vegetation arrests the attention on all sides. The street of the village has an avenue of the Otaheite apple (*Eugenia malaccensis*), which carpets the road with its purplish-red stamens. *Spathodea*

campanulata, a large tree with reddish-orange flowers, from tropical Africa, has become quite naturalized. The upas tree and the durian both grow in the garden, as well as the talipot or umbrella palm of Ceylon (*Corypha umbraculifera*), which has fan-shaped leaves twelve feet in diameter.

The sea is only six miles off, where there is a large sheltered bay of shallow water, protected by a bold headland and small bays; here search may be made for marine algæ.

About a mile and a half from the village, by a road along the side of the gorge, we come to the famous bath dedicated to St. Thomas the apostle. It is a hot spring of mineral water, efficacious in rheumatic and gouty complaints. This gorge is an unfailing delight for its picturesque beauty, and the botanist finds something new at every step. There is a bridle path across the mountains to Port Antonio, sixteen miles distant by the Cuna-cuna pass. This pass is an easy ride of six and one-half miles from Bath through virgin forest.

The forest commences close at the other side of the village. Most of it at one time or another has probably been cut for negro provision fields, but at a distance only of two or three miles undisturbed forest can easily be found, where the palm, *Calyptrogyne Swartzii*, flourishes, its stems clothed with that rare tropical American fern *Anetium citrifolium*. The John Crow, or Blake mountains, are unknown land, and it is said that the Maroons alone penetrate into their fastnesses in hunting wild pig. Inspector Thomas of the Jamaica constabulary crossed them a few years ago, and published an account of his expedition, but he is the only white man who is actually known to have ventured into them. These limestone mountains are of some considerable elevation (about 2000 feet), and are only ten miles from Bath, seven miles of which can be ridden. They ought to prove a happy hunting ground for the botanist. There are specimens of two species of tree fern, *Cyathea conquisita* and *C. pendula* in the British Museum, collected by Nathaniel Wilson who lived at Mansfield, two miles from Bath, but they have never been found since, and it is quite possible that he may have come

across them near the John Crow mountains where no botanist has ever been since his time. The soil at Bath is alluvial, deep and rich. The rainfall is heavy, being on the borders of the district which is classed by Maxwell Hall as having the heaviest fall, viz., over 100 inches in the year.

The garden is only a remnant of Nathaniel Wilson's garden, but is maintained by government as a small arboretum. It contains several trees of great interest and beauty, and is much more tropical in its aspects than any of the other gardens. Elevation 70 feet; mean annual temperature 79–85° F.

THE FLORA.

Jamaica is a paradise for the botanist, whether he specializes in algæ, fungi, mosses, ferns, or flowering plants. Of ferns there are about 450 species, and of flowering plants 2180 species; a number of both are endemic. Among the flowering plants are not only those found everywhere in the tropics, but types from North, Central, and South America, and the other West Indian islands.

Forty-four new species of mosses from a limited area in the Blue mountains have just been described in *Bulletin de l'Herbier Boissier*. A synopsis of the ferns is now appearing in the *Bulletin of Botanical Department*, Jamaica. Grisebach's *Flora of the British West Indies* is the only book that gives a connected account of the flowering plants. The flora of the whole of the West Indies is being thoroughly worked up now by Professor Urban, assistant director of the botanic garden of Berlin. The results of his labors appear in Engler's *Botanische Jahrbücher*. The monographs in continuation of De Candolle's *Prodromus* also contain later work than Grisebach's. In the *Jahrbuch* of the botanical gardens of Berlin Dr. Mez has published a monograph of the American Lauraceæ, including those of the West Indies.

ELEVATIONS.

The following table gives a general idea of the area in square miles embraced in the different zones of elevation, above sea level, in the several parishes:

Parishes	Area below 1000 feet	1000 feet to 2000 feet	2000 feet to 3000 feet	3000 feet to 4000 feet	4000 feet to 5000 feet	5000 feet and upwards	Total areas in square miles
Kingston	6½	⅔	..	..	..	..	7⅙
St. Andrew	59	54	27	17½	8	½	166
St. Thomas	135	59	35	20	14	11	274
Porteana	94	89	40	32½	17	12½	285
St. Mary	110	116	19	4	..	..	249
St. Ann	85	337	54	..	..	..	476
Trelawny	166	135	32	..	..	..	333
St. James	139	90	5	..	..	..	234
Hanover	161	6	..	..	..	..	167
Westmoreland	235	73	..	..	..	..	308
St. Elizabeth	335	120	7	..	..	..	462
Manchester	42	134	126	..	..	..	302
Clarendon	314	115	45	..	..	..	474
St. Catherine	336	124	10	..	..	..	470
Totals	2217½	1,452⅔	400	74	39	24	4,207⅙

Year	Rainfall divisions				The Island
	N. E.	N.	W. C.	S.	
	In.	In.	In.	In.	In.
1870	110.60	83.09	102.98	61.07	89.43
1871	69.45	41.88	54.56	34.46	50.09
1872	59.42	40.79	51.50	29.02	45.18
1873	84.08	52.64	67.79	47.71	63.06
1874	97.18	68.25	62.97	47.35	68.94
1875	71.89	47.15	56.16	34.47	52.42
1876	90.38	54.71	87.33	52.99	71.35
1877	100.72	56.53	64.06	52.27	68.40
1878	104.12	62.99	72.44	66.11	76.42
1879	122.55	65.44	87.54	79.85	88.84
Means	91.04	57.34	70.73	50.53	67.41
1880	76.37	47.01	64.91	33.47	55.44
1881	91.24	49.42	75.32	58.42	68.60
1882	65.48	43.76	78.59	43.67	57.87
1883	72.30	41.52	78.19	45.02	59.26
1884	69.00	41.87	73.10	43.63	56.90
1885	70.55	52.77	72.62	43.52	59.86
1886	126.61	60.98	88.21	86.64	90.61
1887	80.25	61.07	80.14	61.16	70.66
1888	98.00	54.42	70.43	65.58	72.11
1889	99.81	56.82	75.94	64.02	74.15
Means	84.96	50.96	75.74	54.51	66.54

RAINFALL.

THE JAMAICA RAINFALL FROM 1870 TO 1889.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1870.....	3.99	4.35	3.10	2.79	17.38	3.58	4.33	5.72	8.05	16.74	12.50	9.90	89.43
1871.....	2.40	1.60	2.29	3.46	6.43	1.98	3.79	3.46	5.70	8.88	5.88	4.22	50.09
1872.....	3.00	2.84	3.06	2.06	5.18	2.41	2.89	5.24	4.55	6.09	3.13	4.73	45.18
1873.....	8.15	1.94	5.47	1.15	5.06	2.58	2.56	7.51	10.73	8.57	3.53	5.81	63.06
1874.....	3.44	2.20	0.61	4.40	10.65	3.96	2.51	9.65	6.82	11.69	10.52	2.49	68.94
1875.....	2.57	0.67	2.59	3.05	8.54	3.74	3.87	5.13	7.60	5.58	2.34	6.74	52.42
1876.....	6.00	0.96	1.63	4.68	8.24	5.40	8.15	5.06	5.19	11.36	8.96	5.72	71.35
1877.....	5.94	1.18	5.38	2.91	15.03	6.50	4.68	1.76	5.01	4.50	7 63	7.88	68.40
1878.....	6.35	2.80	2.78	0.70	4.86	6.63	5.85	10.80	7.43	11.29	7.32	9.61	76.42
1879.....	2.81	5.30	6.49	7.28	9.14	10.64	4.47	12.32	7.38	15.96	5.29	1.76	88.84
Means.....	4.46	2.38	3.34	3.25	9.05	4.74	4.31	6.66	6.85	10.07	6.71	5.59	67.41
1880.....	4.36	0.96	1.10	2.77	11.60	3.09	3.86	9.58	3.97	4.00	2.21	7.94	55.44
1881.....	1.22	4.01	1.30	4.63	10.28	5.56	4.77	6.21	7.68	12.08	7.52	3.34	68.60
1882.....	2.92	1.93	3.54	3.32	8.22	2.33	3.76	4.80	8.78	8.96	5.36	3.95	57.87
1883.....	5.49	3.50	4.08	3.34	5.29	4.98	3.15	5.42	7.82	8.15	5.12	2.92	59.26
1884.....	4.72	3.44	2.51	1.85	6.72	6.89	2.52	5.06	6.23	9.52	5.00	2.44	56.90
1885.....	1.73	1.49	1.47	4.73	4.90	3.32	3.02	6.19	6.22	6.37	4.74	15.69	58.86
1886..... ..	5.23	4.65	2.68	6.39	5.30	23.36	6.22	13.54	5.90	7.98	3.70	5.66	90.61
1887.....	6.02	2.32	2.38	4.47	9.32	8.89	7.19	6.91	5.77	8.47	8.17	0.75	70.66
1888.....	1.36	1.89	1.70	3.61	21.24	6.77	2.65	5.47	8.10	4.38	4.59	10.35	72.11
1889.....	4.78	0.90	4.19	6.71	7.82	12.52	6.08	5.12	8.20	10.49	4.37	2.97	74.15
Means.....	3.78	2.51	2.49	4.18	9.07	7.77	4.32	6.83	6.87	8.04	5.08	5.60	66.54

BRIEFER ARTICLES.

VARIATION IN LEAF ARRANGEMENT IN A MAPLE.

SOME weeks ago my attention was called by a colleague here to a young maple tree growing against the south wall of one of the college buildings. This young tree, perhaps ten years old, is limited in its direction of growth by its position, and it receives direct sunlight only when the sun is sufficiently high to shine over the flight of stone steps just east of it. Thus it has only a partial eastern exposure, no northern exposure, and is free only at the south and west. Naturally the tree is unsymmetrical and leans southward, away from the building. Evidently, too, the tree has undergone hardship other than that of unfavorable, or at least limited position, for it has no main stem, and its two or three largest branches do not balance well.

Of these larger branches one is remarkable in the arrangement of leaves and branchlets. The leaf arrangement of this tree is normally opposite, the pairs of leaves alternating regularly, and bearing a bud in each axil. The buds of former years have developed normally, in pairs and alternating. One branch, however, pointing southward and upward at an angle of about 45°, bears leaves and branchlets in threes, the whorls of three alternating regularly, so that the leaves and branches do not stand directly over one another. The branchlets, on the contrary, bear leaves in pairs, regularly alternating and therefore typical in arrangement.

On examining the lateral buds which are borne in the axils of the leaves developed in whorls of three, one sees a possible reason for such a diversity in the phyllotaxy of the branch and of its branchlets. Obviously each axillary bud develops in a space limited by two opposite organs, branch and leaf, capable of offering a certain amount of resistance to any structure developing between them. But on the other two sides no such resistance can be offered, for there is no older and stronger structure. It is true that the base of the petiole of the maple leaf is concave on the upper side, and that it clasps the branch more or less; but obviously far more resistance can be offered to the

growth of a bud and of any of its coverings from the moment of their origin as papillæ on the side of a growing-point, by the branch and the part of the petiole opposite it, than by the thinner, weaker, and really more distant opposite sides of the more or less clasping concave petiole. Examination shows that the outermost bud scales of all the lateral buds of this little tree, whether these buds are borne on the branches with paired leaves or on the one with leaves in whorls of three, are invariably opposite the spaces between branch and petiole, only the bud scales of the second and next inner pair being opposite the branch and petiole. Similar examination of the terminal bud of a branch with paired leaves shows that its outer pair of bud scales are alternate with the preceding pair of leaves, and its paired bud scales are regularly alternate, suggesting the regularity in arrangement of the parts within, and promising a continuance of the regularity in the branch which will develop therefrom next year.

On the other hand, the terminal bud of the one branch bearing its leaves in whorls of three has bud scales in whorls of three, the scales of the outer whorl alternating in position with the three leaves immediately behind this terminal bud, the bud scales of the succeeding whorls alternating regularly, and thus suggesting the same arrangement for the parts within, and prophesying a continuance of this arrangement of leaves on the nodes to be separated by growth of the internodes, and on the nodes to be formed, next season.

It seems to me, therefore, that in this little tree we have not only an interesting case of variation, but also an illustration of those influences — be they merely mechanical, as Schumann[1] would claim, or due rather to the arrangement of the deeper-lying conducting-tissues and hence connected with nutrition — which, if they do not altogether control, at least strongly influence the arrangement of the leaves and other structures formed at successive nodes. I am unable to discover any indications of what might have caused the different leaf-arrangement in the bud from which the present branch bearing leaves in threes has developed. It is of course easy to speculate as to possible causes, and perhaps if the branch were cut off, and examined microscopically at the base, evidences of the cause of the present difference might be found; but there are reasons which seem to me sufficient, for allowing this branch to grow on unmeddled with. We have then the variation, its cause being unknown. In the regular alternation of the leaves and the

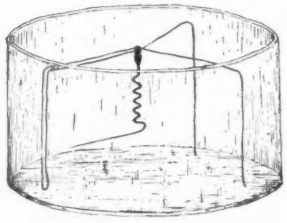
[1] Morphologische Studien, Heft I: Die Blattstellungen in gewundenen zeilen.

bud scales, whether in threes or twos, we have at least a suggestion that the "sport" was caused by the same influences which continue to affect if not to effect the alternation; namely, on the one hand, the mechanical resistance which the growing papillæ, which develop into leaves or branches, would encounter were they to grow in certain easily recognized directions, and their freedom from this resistance if growing in other directions; or, on the other hand, the disposal of the subjacent conducting-tissues, which would affect the nutrition of the vegetating point, and so might favor the formation and growth of leaf and branch papillæ (*Anlagen*) in positions alternate rather than opposite to older or already developed parts.—GEORGE J. PEIRCE, *Stanford University*.

HYGROMETER MADE WITH ERODIUM AWNS.

[THE following letter, together with some Erodium awns, was sent me a short time ago by Mr. Walter R. Shaw. I find upon trial that the awns are admirably fitted for the purpose indicated, and that the construction of an efficient hygrometer with them is a simple operation. Believing that others will be glad to make use of this method of demonstration, I have asked the privilege of publishing the letter and the sketch that accompanied it.—J. C. ARTHUR.]

I have found the awns of *Erodium cicutarium* an excellent substitute for those of Stipa in the Darwin transpiration hygrometer. Erodium is very common in some parts of California. A piece of iron wire bent in the form of a tripod serves to support the awns in the crystallizing dishes better than the mechanical cross bars that were supplied some time ago. The seed on the awn is easily attached to the tripod by a small bit of wax or paraffin with a hot needle. The tripod has the advantage that it may be instantly revolved to any position inside the dish without throwing the awn out of the axis of the vessel. The Erodium awn carries its own pointer. On the whole, less dexterity is required in its manipulation, and it has been shown to be more sensitive to humidity than the longer awns of Stipa.—WALTER R. SHAW, *Stanford University*.



Hygrometer made with crystallizing dish, in which an Erodium awn is supported on a tripod formed by bending a single piece of iron wire.

A METHOD OF PRESERVING ALGÆ.

ALGÆ for demonstration purposes may be preserved without trace of shrinkage and mounted for permanent use in the following manner: Kill and fix in Flemming's weaker formula (10^{cc} 1 per cent. osmic acid; 10^{cc} 1 per cent. acetic acid; 25^{cc} 1 per cent. chromic acid; 55^{cc} distilled water). This may be used from one-half hour to twenty-four hours or more without injury to delicate tissues. Next drop 10 per cent. glycerine directly into the fixative. Be careful to allow each drop to diffuse before adding more. This guards against shrinkage which is caused by diffusion currents if glycerine is added too rapidly. Continue adding drop by drop until enough glycerine has been put in to cover the specimens when evaporated. The fixative and water should now be allowed to evaporate in a watch glass where a large surface is exposed. The specimens may now be handled with a needle or knife and arranged on the slide under a dissecting microscope. A drop of pure glycerine or of glycerine jelly makes a very satisfactory mount. Glycerine jelly has to be used very carefully, but it is the more satisfactory when it can be used with success. Filamentous forms should be cut while fresh into pieces of convenient length for handling.

This glycerine method is extremely convenient for preserving fruiting forms, for demonstration of swarm spore and zygospore formation. The more delicate stages may be fixed and mounted on the slide so that they need only be handled once. The method was devised and thoroughly tested in the laboratory of Lake Forest University last year. Since leaving Lake Forest I have used it successfully in preserving red algæ at Wood's Holl. Some of them, as Dasya, retain their color almost perfectly under this treatment. Although color in green algæ is more or less sacrificed, the chromatophores retain their shape perfectly, while the cells as a whole become even clearer than fresh material.—CHAS. THOM, *Missouri State University*.

NOTES ON THE WOODY PLANTS OF THE SOUTH ATLANTIC STATES.

I HAVE collected at several places in the mountains of the southern states a Fothergilla which is evidently distinct from the coastal plant. Descriptions of both are given, taken from a large number of specimens. The Alabama plant I have not seen.

FOTHERGILLA CAROLINA (L.) Britt. A low shrub with erect or spreading branches, reaching a height of 0.6^{m} or rarely 1^{m}: leaves 2 to 4^{cm} long, 1 to 2^{cm} wide, oblong or obovate, rounded or cuneate at base, obtuse and usually emarginate at apex, denticulate to coarsely crenate above, thickish, dull green and smooth on the upper surface, below paler and somewhat glaucous, smoothish or soft pubescent with brown or fulvous hairs, with 3 or 4 pairs of prominent straight veins; petiole pubescent, 2 to 4^{mm} long; stipules minute, 2 to 3^{mm} long, deciduous: terminal bud and young twig soft pubescent, bud 3 to 4^{mm} long: style 6 to 8^{mm} long: capsule clothed with fulvous pubesence, the styles erect and parallel: seed 4 to 5^{mm} long.

I have been unable to secure specimens of this plant from farther south than southern South Carolina, but expect that the plant which has been collected in central Alabama is referable to this species.

Fothergilla monticola, sp. nov. A bushy shrub, commonly dividing near the base into erect virgate branches, with dark brown or reddish minutely roughened bark, reaching an average height of about 1.2^{m}, or exceptionally even 2.5^{m}: leaves 8 to 12^{cm} long, 5 to 8^{cm} wide, oval, broadly obovate or nearly orbicular, cordate, subcordate or truncate and unequal at base, rounded or obtusely pointed at apex, irregularly crenulate or undulate even to the base, membranaceous, bright green on both sides, smooth or nearly so even when young, the 4 to 6 pairs of prominent parallel veins terminating in short mucros; petiole slender, 1 to 1.5^{cm} long; stipules ovate-lanceolate, acuminate, 5 to 7^{mm} long, somewhat persistent: terminal bud naked, flattened, sericeous, about 5^{mm} long: twigs mostly smoothish, red-brown: flowers unknown, but style 1^{cm} long, evidently longer than in *F. Carolina:* spikes 3 to 5^{cm} long: capsules larger than the preceding, clothed with grayish pubescence; styles divergent: seed grooved at the top, 6^{mm} long.

Rocky woods, mountains of Virginia to South Carolina, between 400 and 1200^{m} elevation.

The only published name which could possibly apply to this species is *Fothergilla major* Lodd.[1] This description is from cultivated plants which seem to be only vigorous specimens of *F. Carolina,* and are described as having spikes over three inches in length, late in flowering, and leaves broad and much toothed. The limited distribution of *F. monticola,* and the fact that none of the early American botanists recognized more than one species, though Elliott remarks that the species (the coast plant) is variable in the color of

[1] Botanical Cabinet, 1720.

its stamens, and possibly contains more than one species, would seem to show that the mountain species was unknown to them. Dr. M. A. Curtis was aware of the occurrence of a Fothergilla in the western part of North Carolina of greater size and with larger leaves than the plant of the eastern part of the state.

ZENOBIA SPECIOSA PULVERENTULA (Michx.). (*Andromeda speciosa* var. *pulverentula* Michx. Fl. 1 : 256). Leaves thinner, more oval, crenate, persistently densely white pulverulent beneath.—A well-marked form, sometimes growing with the type, but usually separate, occurring in North and South Carolina.

SMILAX AURICULATA Walter. There seems to be no reason why this name should not replace the later *S. Beyrichii* of Kunth. The only objection urged against applying Walter's description to this species is that he gives the color of the berries as being purple, while they are black when ripe. All through the winter, however, until they ripen in the spring, they can be found all shades of purple.

SMILAX LAURIFOLIA BUPLEURIFOLIA Delile occurs from eastern South Carolina, where it was originally collected by Curtis, to southern Virginia. Its very long and narrow leaves make it quite distinct from *S. laurifolia*, though in other respects I can detect no difference.

SMILAX LANCEOLATA L. is usually considered to be an annual-fruiting species, but the few specimens which I have found in fruit evidently ripen their seed the spring after the summer when they flowered. It does not flower until July, and the berries, which by winter are yet small, remain green or somewhat reddish until the following spring.

Quercus pagodæfolia (Ell.), nom. nov.

Q. falcata var. *pagodæfolia* Ell. Bot. 2 : 605.
Q. digitata pagodæfolia (Ell,) Ashe, Handbook of N. Car. 47. 1896.

Leaves oval or oblong, 8 to 12^{cm} long, 4 to 8^{cm} wide, with 3 to 6 pairs of prominent straight veins, and as many usually entire narrowly triangular lobes separated by deep rounded sinuses, the lobes divaricate or projecting somewhat towards the apex, thick, above dark green, below persistently white tomentose; petiole 3 to 4^{cm} long, slender, tomentose: twig 2 to 3^{mm} thick, persistently white tomentose: buds 2 to 4^{mm} long, acutish, bright brown, the scales nearly smooth: cup 1 to 2^{cm} wide, shallow, scales large for the group, appressed, smooth or downy; nut barely 1^{cm} thick, scarcely larger than that of *Q. digitata*, globose, one-half enclosed in the cup: seed yellow and bitter.

A large tree reaching a height of 25 to 32^{m} and a diameter of 0.8 to 1.1^{m}, with an oval or oblong crown and spreading branches, the rough checkered bark of the trunk dark gray or blackish and somewhat striped, that of the limbs smoothish and dark gray. River swamps eastern Virginia and North Carolina to southwestern Georgia. Although not a common tree, several specimens usually occur together where it is found. It is usually associated with *Quercus Michauxi*, *Q. nigra*, and *Liquidambar*. The original locality of Elliott is on the Roanoke river near Weldon, N. C.; he also found it in South Carolina. I have found it on the bottom lands of the Roanoke, Neuse, and Cape Fear rivers in North Carolina, where it extends some distance westward in the Piedmont plateau region; and in southwestern Georgia where it occurs along the Flint river.

This tree is evidently not a hybrid, as it shows no intermediate characters between *Q. digitata* and any other species. The shape of the nut is globular as is that of *Q. digitata*, the cup somewhat deeper; the pubescence is white, while that of *Q. digitata* is more often tawny and is more persistent than that of *Q. pagodæfolia*.

QUERCUS TEXANA, which is a rare tree in the Atlantic states, seems to be entirely absent from the coastal region. In North Carolina it is confined to the Piedmont plateau, but does not occur above an altitude of 200^{m}. In northern Georgia it is found as high as 350^{m}. In certain parts of the Flint river valley of southwestern Georgia it is more common, often being associated with the red oak, from which, under the common name of spotted oak, it is often not distinguished by the inhabitants.

ILEX LÆVIGATUS (Pursh) Gr. occurs abundantly in certain parts of eastern North Carolina and South Carolina, though it does not seem to have been recorded at all from this region. There can be but little doubt that this is the *Ilex lanceolatus* of Chapman's *Flora* (*Prinos lanceolatus* Hill, Veg. Syst. **16**: 57. *pl. 61*) as the description and distribution agree well with that given for the *Prinos lanceolatus*. In this case the earlier *lanceolatus* will replace *lævigatus*. I have specimens of the plant from nine localities in North and South Carolina, all of them between 40 and 100 miles of the coast.

ILEX AMELANCHIER M. A. Curtis. Several stations have been found for this uncommon plant in North Carolina and one in southern Virginia. It has not hitherto been reported from further north than the original station at Society Hill, S. C. While not entirely confined to the Piedmont region of the Carolinas it seldom enters the coastal plain, and does not occur above an altitude of 350^{m}.

Ilex Beadlei, nom. nov. *Ilex mollis* of southern authors, and in part that of Gray's Manual. *Prinos dubius* Don[2] is usually given as a synonym for this species, but the original description will scarcely apply to *I. Beadlei*, and the distribution assigned to *Prinos dubius*, from North Carolina to New Jersey, barely even extends as far south as the most northern point where *I. Beadlei* is known to occur. The distribution of *I. Beadlei* is from Kings mountain, North Carolina, westward through the southwestern part of North Carolina, to northern Georgia, eastern Tennessee, and probably to northern Alabama. This species reaches its best development and is most abundant in and around Ocoee county, Georgia. The name proposed for the species is in honor of Mr. C. D. Beadle, Curator of the Biltmore Herbarium.

ILEX AMBIGUA (Michx.) Chapm., which is the smallest and most delicate of the southern species of the genus, probably does not occur north of the Neuse river in North Carolina, its distribution terminating with that of the sand hills on which it grows.

RHUS AROMATICA MOLLIS (Gray) (*R. Canadensis* var. *mollis* Gr.) occurs in North and South Carolina only in the Piedmont region, not being found above 250^{m} altitude. Besides being densely pubescent beneath, the leaflets, in all the specimens which I have seen, are considerably broader than in *R. aromatica*.

DENDRIUM BUXIFOLIUM PROSTRATUM (Loud.) (*Leiophyllum prostratum* Loud.), collected from the summit of Table Rock at 1000^{m} altitude, has nearly the same characters as that from the summit of Roan mountain, at nearly twice that altitude, while *B. buxifolium*, collected at an altitude only a few meters below that of Table Rock, has the oblong and more scattered leaves of the coast plant, and can scarcely be distinguished from it in the dried material. Though slight, the characters between the two plants seem to be well marked and persistent.—W. WILLARD ASHE, *Forester, Geol. Survey, Raleigh, N. C.*

[2] Mill 2 : 20.

OPEN LETTERS.

ON THE VALUE OF SECTION NAMES.

I HAD imagined that when a section was given generic rank, there would not be any difference of opinion, at the present day, as to the generic value of the section name, provided always that it agreed in form with generic names, and was the earliest name (not preoccupied) for the group. In the just published *Contrib. U. S. Nat. Herb.* **5**: no. 3, Dr. Rose takes a different view, and uses names for two genera (*Vaseyanthus* and *Brandegea*) which are of later date than section names which he places in their synonymy. It is evident that he feels justified in doing this because the generic names were proposed as generic names at a time when the section names were not known to represent the same groups. As the matter is of some importance, it may be well to test it by these cases, so I give the two alternatives. Dr. Rose writes thus:

(1) GENUS, Vaseyanthus Cogn. 1891; SYN. Echinocystis § Pseudoechinopepon Cogn. 1890; TYPE, *Vaseyanthus Rosei* Cogn. 1891.

(2) GENUS, Brandegea Cogn. 1890; SYN. Sicyos § Heterosicyos S Watson. 1888.

It seems to me it should be:

(1) GENUS, Pseudoechinopepon Cogn. 1890; SYN. Vaseyanthus Cogn. 1891; TYPE, *Pseudoechinopepon Brandegei* (Cogn. 1890).

(2) GENUS, Heterosicyos S. Wats. 1888; SYN. Brandegea Cogn. 1890; TYPE, *Heterosicyos minimus* (S. Wats. 1888).

—T. D. A. COCKERELL, *Mesilla, N. M.*

CURRENT LITERATURE.

BOOK REVIEWS.

Index to Saccardo's Sylloge.

A COMPLETE index to Saccardo's great work on fungi has been compiled by Dr. Sydow.[1] The first half of the volume was issued in advance, and was noticed in this journal for last May. The index is divided into five parts: the first part includes species growing on living or dead parts of plants (858 pages); second those on living or dead parts of animals and man (14 pages); third those found on artificial substrata, such as paper, bread, etc. (30 pages); fourth those on earth, stones, etc. (137 pages); and fifth those that are fossil (13 pages). The bacteria are excluded from the index. The alphabetical arrangement is by genera, with species under each genus. The kind of substratum (hosts being mentioned by name), and the geographical distribution are also given in the same line.

The index is almost invaluable to one who uses the work much, and is a fitting complement to the eleven volumes of specific descriptions. The typography is admirably suited to ready reference.—J. C. A.

The bacteria.[2]

THE author of this valuable addition to bacteriological literature is well known to English readers through the translation of his *Introduction to Practical Bacteriology*, as well as through his original contributions to our knowledge of bacterial structure and function. The present work is an exceedingly useful and usable compilation. It deals with such questions as the relationship of bacteria to other groups of organisms, and the orderly arrangement possible within the group itself; with the morphology and chemistry of the cell membrane, the structure, chemistry and reaction to stain of the cell contents, the problematic cell nucleus and *Centralkörper;* and

[1] SACCARDO, P. A.—Sylloge fungorum omnium hucusque cognitorum. Vol. XII; Index universalis et locupletissimus generum, specierum, subspecierum, varietatum hospitumque in toto opere (vol. I–XI) expositorum. Auctore P. Sydow. Roy. 8vo. pp. 1053. Berolini: Fratres Borntraeger. 1897.

[2] MIGULA, DR. W.—System der Bakterien. Handbuch der Morphologie, Entwickelungsgeschichte und Systematik der Bakterien. Erster Band. Allgemeiner Teil. Mit 6 Tafeln. Jena: Gustav Fischer. 1897.

with the question of bacterial motility including all the vexed and difficult problems connected with the origin, distribution and significance of the flagella. There are important chapters upon growth and division and the formation of cellular unions or colonies, and upon spores and gonidia, and pleomorphism and variability. The "general part" comprised in the volume before us, and presumably to be supplemented some day by a "special part," concludes with an interesting section upon the biological characteristics of bacteria, in which are discussed such phenomena as pigment production, anaerobiosis, parasitism, phosphorescence, the action of light and temperature, and the special metabolic activities displayed by the sulphur, the iron, and the nitrogen bacteria. The merit of the whole treatise is that it brings together the information obtained through the researches of the past few years and presents it in a careful and lucid way.

The author's system of classification is already well known from its appearance something over a year ago in *Die Natürlichen Pflanzenfamilien* (Lfg. 129).[3] It is simple and consistent, and at least does not include hypothetical genera to be hereafter discovered for the delectation of the scientific imagination.

It may be questioned whether our author has made the best use of his space in threshing over the old facts of the historical development of classification and nomenclature in the same thoroughgoing manner in which it has already been done. It must be confessed one is a little weary of seeing in monograph and text-book the same old "systems" trotted out for inspection again and again. The system of de Toni and Trevisan, for example, has certainly not proved such a help to bacteriology that we are justified in keeping it constantly before our eyes. Such systems are the flotsam and jetsam of progress, and if they are fain to sink of their own weight should be allowed to do so. The fetish of completeness, however, is conspicuous throughout the book, and much valuable space is sacrificed to it. The irrelevant and the trivial do not deserve a place by the side of the significant and essential, and the writing of such a book as this should presuppose the selection and sifting of material.

The author's treatment of the cell nucleus question is, on the whole, discriminating and fair. He refuses to accept Bütschli's statements as to the existence of a *Centralkörper* in bacteria, and denies that bacteria possess a true cell nucleus "like the cell nucleus of higher plants," but is inclined to look upon the metachromatic granules observed in the cell contents as a sort of primitive nuclear substance.

Migula takes germination as the criterion of a spore, a process which in a true spore differs essentially from the proliferation of a vegetative cell, and on this ground gives no credence to the existence of arthrospores. He does

[3] See BOT. GAZ. **21**: 243. Ap. 1896, and American Naturalist, June 1896.

not lay so much stress as many recent writers have done upon the claims for extensive pleomorphism and variability among bacteria, and seems not to be acquainted with some of the available data in this field.

The index of the book is somewhat inadequate for a compilation of this character, and might be enlarged to advantage. The most serious typographical error that we have noticed is the mistake in numbering and placing Plates IV and V, so that each plate is faced by the description of the other. But when all shortcomings are taken into consideration, it still remains true that Dr. Migula's work is a distinct aid to all workers in bacteriology, and should give an impetus to the study of the purely scientific aspects of the subject.—E. O. J.

MINOR NOTICES.

THE PROCEEDINGS of the tenth annual convention of the Association of Agricultural Colleges and Experiment Stations has recently been issued in Bulletin no. 41 of the Office of Experiment Stations. They contain only one botanical paper, a vigorous presentation of the place of vegetable physiology in the curriculum of the agricultural colleges, by Professor Geo. E. Stone, of Amherst, Mass. This article, while addressed to agricultural colleges, is equally applicable to the conditions existing in most of the higher educational institutions in the United States, and deserves a wider reading than its form of publication is likely to bring. The author justly states that "there has been no branch of botany so neglected in our country as the physiology of plants." A very general awakening, however, has been recently experienced. As a pedagogical subject, nevertheless, it is still in a very unsettled condition, and it has been called upon to meet the damaging influence of specialists in other lines of activity, who permit inertia and mistaken notions to influence their attitude toward the new aspirant for position. The following sentences, quoted from the article, are so well said, and so much in need of being said, that they are reproduced here, and it is to be regretted that room is not available for more.

"The necessity of defining a branch like physiology is in itself a reflection on our botanical development, especially when there are so many excellent text-books treating physiology in a distinctly characteristic manner. Nevertheless such misconceptions exist, and I feel justified in calling attention to them. There has never been any question as to what physiology implied among the animal physiologists; neither has there been any among European vegetable physiologists. But right here in our American agricultural institutions we have had professors of botany who did not, and do not today, seem to know exactly what ground this subject covers. One institution that I have in mind has advertised for years a thorough and complete equipment for work in vegetable physiology, and yet this very same institu-

tion has scarcely had a single piece of purely physiological apparatus in its outfit during the whole time. The institution I refer to by no means stands alone in the matter. There are others holding the same conception of physiology. The fact in regard to the matter is that there are still some botanists who insist in calling the study of the structure of a stem or leaf, or the mounting of a slide, etc., physiology.

"Physiology as treated by such eminent physiologists as Foster, Bowditch, Ludwig, DuBois Reymond and others, implies function, and I cannot understand how a botanist can even have looked into the text-books of Vines, Sachs, Pfeffer, Frank, and others, without obtaining a similar conception. Inasmuch as physiological botany concerns itself with function, it is essential that any extensive course in this branch must be preceded by a fairly good course in anatomy and histology. I believe, however, that in every elementary branch of botany the function of the plant should be taken into consideration.

"For a practical course in physiology considerable apparatus is needed. This is generally expensive, and when imported not always satisfactory from the American idea of machinery. Much of the apparatus can be constructed in the laboratory, providing a good set of tools is at hand. Much time is saved by having the apparatus all ready to put together at short notice, and for this purpose it is necessary to have a good stock of glassware on hand, which should be fitted up for the various experiments."

The whole article is as practical and incisive as the few sentences quoted indicate, and merits the attention of botanical teachers.—J. C. A.

WORK ON the North American mosses proceeds steadily from the herbarium of Columbia University. The last paper is "A Revision of the North American Isotheciaceæ and Brachythecia," by A. J. Grout.[4] Of the quality of such work only one who goes over it critically can judge; but one has every reason to accept this as a real contribution to the knowledge of these mosses, and the more since the author had the benefit of the advice and the suggestions of Mrs. E. G. Britton.

Mr. Grout adopts *Entodon* for our species of *Cylindrothecium* and *Platygyrium*, *Pylaisiella* for *Pylaisia*, *Holmgrenia* for *Orthothecium;* removes *Homalothecium* from the Isotheciaceæ; and drops *Isothecium* from the list of North American genera. Various changes are made in the list of species, both as to nomenclature and their presence in this country. Over most of these we breathe a sigh of relief, particularly over those affecting the names recently published by Kindberg and C. Müller. Through these the author cuts a wide swath. Four, only, stand; the list of synonyms contains no less than twenty-seven names by these authors, seventeen by Kindberg and ten

[4] Reprinted as a doctor's thesis from Mem. Torr. Bot. Club **6**: 131–210. 1897.

by C. Müller and Kindberg, while three are relegated to the doubtful list, and two to the rank of varieties. *Brachythecium asperrimum* holds the record with *four* Kindbergian names as synonyms! Let the good work go on.—C R. B.

AT THE TIME of the death of Dr. Schröter, December, 1894, the *Pilze* of the *Kryptogamen-Flora von Schliesen* was within three parts of completeness. Part of the manuscript for the remainder was prepared, but about one signature had not been begun. The publishers have now issued one of the remaining parts[5] which carries the work through the *fungi perfecti*, and through eighty-five species of the *fungi imperfecti*, which is all the material the author left in readiness for the press.

The publishers express regret that they have been unable to secure a suitable person to complete the work upon the original lines. They therefore purpose to issue shortly a final part, to contain such species as Schröter had indicated, as shown by his fragmentary notes and the herbarium deposited in the Pflanzenphysiologisches Institut of the University of Breslau. It will also contain a supplement giving Schröter's changes and additions to the preceding parts, and will close with an index to the second volume.—J. C. A.

NOTES FOR STUDENTS.

FRIEDRICH OLTMANNS[6] has described the results of a recent study of the swarm spores of certain Phæophyceæ. He claims to have disproved the statements of Berthold,[7] as quoted in the standard texts, that in *Ectocarpus siliculosus* a large zoospore comes to rest, becomes attached to one to four small zoospores, and then fuses with them; also that zoospores from plurilocular sporangia fuse in pairs. The form most fully studied was *E. criniger*, in which unilocular sporangia, if present, were not discovered. The claim is that one is dealing here, not with a primitive condition of sexuality, but rather with infusorians which are eating the algal zoospores. The number of nuclei in the so-called zygote is invariably one greater than the number of chromatophores, and the extra nucleus differs from the others in appearance and staining reactions. The process of digestion of the spores can be followed, and the wastes are ejected as minute balls. These facts point to the infusorial nature of the larger organism. This conclusion does not deny all

[5] SCHRÖTER, J.—Kryptogamen-Flora von Schliesen, Dritter Band: Pilze. Zweite Hälfte, vierte Lieferung. 8vo. pp. 385–500. Breslau: J. U. Kern's Verlag. 1897. *M* 3.20.

[6] Ueber Scheincopulationen bei Ectocarpeen und anderen Algen. Flora **83**: 398–414. 1897.

[7] Die geschlechtliche Fortpflanzung der eigentlichen Phaeosporeen. Mitth. d. zool. Stat. Neapel **2**: 401. 1897.

sexual fusions among the spores of Algæ, but may explain many "abnormal" processes, such as the fusion of three or four zoospores in Acetabularia, etc. Many appearances in Dasycladus are due to abortions, the protoplasm having emerged from the mother cell before the zoospores are perfectly formed.

The author believes that Berthold saw nothing but the activity of infusorians, and confirms his views by drawings from some of Berthold's preparations. The fusion of nuclei in the zygote is nowhere seen. That Berthold found zygotes in only a part of his cultures, that he had so many female and so few male zoospores, and that his zygotes never germinated, all go to prove that the bodies were really infusorians. Oltmanns obtains his best results in cultures from three to four days old, those younger not giving the infusorians time to come into sufficient prominence. One can but regret that so important a paper should be accompanied by drawings so small as to make it difficult to distinguish chromatophore from nucleus, to say nothing of telling a zoospore nucleus from that of an infusorian.

Berthold's reply[8] immediately follows. Since Thuret, no one has denied that spores from plurilocular sporangia could germinate without fusion. Oltmanns did not see the sexually formed spores at all, and what he describes as Chytrideæ were described by Berthold in 1881 as products of the disorganization of male zoospores. The genuine zygotes are formed very soon after the spores are formed, and if formed at all are exceedingly numerous. Fusion of more than two zoospores is very rare. The existence of the extra (infusorian) nucleus is to be doubted. A series of memoranda, made while studying the living material, shows how some cultures could be recognized as composed of male, others of female zoospores, and still others of neutral spores capable of direct germination. From one lot of zygotes plants with plurilocular sporangia were finally obtained. Spores of one culture were nearly all alike; and cultures of male and female zoospores when mixed gave zygotes in the greatest number.

We agree with the two authors that little more is to be learned from mere discussion. Such directly conflicting statements can only be reconciled by further investigation.—W. D. M.

DR. C. O. TOWNSEND[9] has further investigated the relation of the nucleus to cell wall formations in a large series of plant cells. He finds that in every case the presence of a nucleus is necessary to enable a mass of protoplasm to enclose itself with a wall. This influence of the nucleus, however, can be transmitted to considerable distances between parts of the same cell separated

[8] Bemerkungen zu der vorstehenden Abhandlung von Fr. Oltmanns. Flora 83:415–425. 1897.

[9] Der Einfluss des Zellkerns auf die Bildung der Zellhaut. Inaug. Diss. Jahrb. f. wiss. Bot. 30:—. 1897. [Heft. 4.]

by plasmolysis, and from one cell to another, provided only that protoplasmic continuity through living fibers is maintained. The author believes that Palla's failure to observe such fine connecting fibers between plasmolyzed masses in pollen tubes led to his erroneous conclusion that the nucleus is not necessary to cell wall formation. Very interesting is the fact that mere contact between two plasma masses is not sufficient for the transmission of the formative influence of the nucleus from one to the other. Just what this rôle of the nucleus is in cell wall formation the author does not attempt to state.—R. A. H.

DR. C. ISHIKAWA of the Imperial University, Tokyo, Japan, has published a third paper[10] in his series of "Studies of reproductive elements." It treats of the pollen grains of *Allium fistulosum*, with special reference to the process of chromosome reduction. In this process he finds some important deviations from what has hitherto been regarded as typical of flowering plants. Although he did not succeed in observing the original delimitation of the sporogenous region from the ordinary tissue of the anthers, he obtained very young sporogenous cells in stamens which were just making their appearance as protuberances on the flower disk. In these early sporogeneous cells the nuclei were already distinguishable by poverty of chromatin, and in division showed the reduced number (eight) of chromosomes, the division being described as heterotypic. The chromosomes split longitudinally, and the segments during metakinesis remain attached by their ends so as to form rings. In the pollen mother cell the spirem is apparently one continuous ribbon, which, after a synapsis stage, becomes divided into segments having the chromatin granules arranged in double rows. The segments shorten and become sharply bent at the middle. Longitudinal fission is now complete, and the bent segments attaching themselves together in pairs at the point of bending give rise to eight X-shaped figures which resemble the tetrads of some animals. Metakinesis proceeds according to the heterotypic method. Arriving at the poles of the spindle, the eight V-shaped daughter chromosomes break transversely at the angle, and form sixteen rod-shaped granddaughter chromosomes. No complete resting condition ensues, but division of the pollen daughter cell into the pollen grains follows at once, according to the heterotypic method. The next stage, the formation of the vegetative and generative nuclei, presents no unusual phenomena. It may be added that in the first division of the pollen mother cell bodies resembling centrosomes were frequently observed.

Doubtless the most interesting observation in this account of spermatogenesis is the early reduction of the number of chromosomes. In all other flowering plants in which chromosome reduction has been investigated it is

[10] Die Entwicklung der Pollen-Körner von *Allium fistulosum* L., ein Beitrag zur Chromosomen Reduktion im Pflanzenreiche. Jour. Coll. Sci. (Tokyo) **10**:—.

said to take place in the pollen mother cell. So it has been described for *Lilium Martagon* by Strasburger, Guignard, Farmer, and Miss Sargant; also for *Larix Europæa* and other plants. In all these cases, too, the chromosomes are distributed by means of two longitudinal fissions; while in *Allium fistulosum* their distribution in the second division of the pollen mother cell is effected by transverse fission. It will be noted that in so far as the reduction in *Allium fistulosum* deviates from the ordinary plant type it approaches what has been reported in certain animals, especially in some copepods and Gryllotalpa, where the second division of the spermatocytes is attended by transverse splitting of the chromosomes, and the reduced number of chromosomes appears early, even as early in *Cyclops brevicornis*, according to Haecker, as the primordial cells of the blastula stage.

Transverse fission of chromosomes in plants has been reported by Calkins in Pteris and Adiantum, by Mottier in Lilium, and by Schaffner in *Lilium Philadelphicum*.—W. R. S.

NEWS.

THE SOCIETY for the promotion of Agricultural Science, at its recent meeting in Detroit, elected Professor B. D. Halsted, of New Brunswick, N. J., president for the ensuing year. The next meeting will be held in Boston in August 1898. The society includes a considerable proportion of active botanists among its members, and many papers of botanical interest are presented before it.

TO DETERMINE more exactly the distribution of the several trees popularly known as pignuts (including *Hicoria odorata* or *H. microcarpa*), Mr. W. W. Ashe, forester of the North Carolina Geological Survey, would be glad to get specimens of these trees, especially from Michigan, central New York, New Jersey, Pennsylvania and Delaware, and from all the southwestern states. The essential parts of a hickory specimen are vigorous twigs with well developed buds, and fruit and leaves. If desired he will return any material sent, and will determine any for persons wishing it. He may be addressed at Raleigh, N. C.

THE SUBTROPICAL LABORATORY at Eustis, Florida, under the direction of the Division of Vegetable Physiology and Pathology of the Department of Agriculture, has been abandoned as a station, and Messrs. Swingle and Webber should hereafter be addressed at Washington. The tropical work, however, will not be discontinued, but will be conducted hereafter from Washington as headquarters. A small garden tract and laboratory have been secured at Miami, Florida, where experiments can be conducted, and where work can be done with laboratory facilities whenever desired. It is expected to make a feature of introducing and testing varieties of tropical plants which can be grown successfully in the tropical and subtropical portions of the United States. Extensive experiments have been made in crossing and hybridizing the orange and other citrous fruits, pineapples, guavas, etc., and the resulting hybrids will be cultivated in this garden. It will also serve as a tropical station for amelioration experiments in the modification of some of our native fruits.

IN THE AMERICAN NATURALIST for October there appears a brief biographical sketch, with portrait, of the late Dr. James Ellis Humphrey. The sudden death of this most promising young American botanist came as a great shock to the whole botanical fraternity. From the sketch referred to the following details of his life and work are selected:

He was born in Weymouth, Mass., August 5, 1861, and received his early education in the Weymouth schools. In 1886 he graduated from the Lawrence Scientific School of Harvard University, with the degree of S.B., and was at once appointed an assistant under Professor Goodale. In 1887 he became instructor in botany in Indiana University, and in 1888 was appointed botanist in the Agricultural Experiment Station at Amherst, Mass., where he remained until 1892. At Amherst he continued his studies under the direction of Harvard, and in 1892 received from the university the degree of Sc.B. From that time until 1894 he studied under Professor Strasburger at Bonn, and returning to America was made a fellow in the Johns Hopkins University. In the next year he was appointed lecturer in botany in the same institution, and in the present year was advanced to an associate professorship. In June he visited Jamaica with a party of students, where he died August 17.

Dr. Humphrey's first published paper was on the development of the frond of the alga *Agarum Turneri*. At Amherst he naturally paid large attention to the fungi, and the reports of the Experiment Station contained many of his contributions upon plant diseases. In Strasburger's laboratory he directed his attention to cytological studies, and most of his later publications have been in this field. It was in the direction of cytological work that his botanical friends expected large things of him. For several years he has been the American correspondent of the *Botanische Centralblatt*, and also translated and edited Zimmermann's *Botanical Microtechnique*. At the time of his death he was one of the associate editors of the reorganized *American Naturalist*.